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US ARMY
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AD-A181 947

LEVEL FLIGHT PERFORMANCE EVALUATION OF THE UH-60A HELICOPTER WITH THE PRODUCTION EXTERNAL STORES SUPPORT SYSTEM AND FERRY TANKS INSTALLED

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SEPTEMBER 1986

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FINAL REPORT

US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523-5000

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SECURITY CLASSIFICATION OF THIS PAGE

AD-A181947

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY: U.S. ARMY AVIATION SYSTEMS COMMAND

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release, distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S): AEFA PROJECT NO. 86-01

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: U.S. ARMY AVIATION ENGINEERING FLIGHT ACTIVITY

6b. OFFICE SYMBOL (If applicable):

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS (City, State, and ZIP Code): EDWARDS AIR FORCE BASE, CALIFORNIA 93523-5000

7b. ADDRESS (City, State, and ZIP Code):

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: U.S. ARMY AVIATION SYSTEMS COMMAND

8b. OFFICE SYMBOL (If applicable):

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS (City, State, and ZIP Code): 4300 GOODFELLOW BLVD. ST. LOUIS, MO 63120-1998

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
68-6BE159-01	68-EC		

11. TITLE (Include Security Classification): LEVEL FLIGHT PERFORMANCE EVALUATION OF THE UH-60A HELICOPTER WITH THE PRODUCTION EXTERNAL STORES SUPPORT SYSTEM AND FERRY TANKS INSTALLED. UNCLASSIFIED

12. PERSONAL AUTHOR(S): ROBERT M. BUCKANIN, WILLIAM A. KELLY, JAMES L. WEBRE, THOMAS L. REYNOLDS, ROY A. LOCKWOOD, RANDALL W. CASON

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 28/05 TO 19/06/86	1986 SEPTEMBER	74

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): External Stores Support System, Level Flight Performance Testing, UH-60A Helicopter

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Limited level flight performance testing was conducted on a sixth year production UH-60A helicopter equipped with a production external stores support system (ESSS) and four preproduction external fuel tanks. These tests were conducted to provide the US Army Aviation Systems Command with level flight power required data to determine if the UH-60A would still meet the selfdeployment requirement described in the Material Need Document if the General Electric T700-GE-700 engines were replaced with T700-GE-701's. Sikorsky Aircraft Division of United Technologies Corporation claimed a drag reduction for the production ESSS over the prototype previously tested. A total of 13.9 productive flight hours were flown at Edwards AFB, and Bakersfield, California between 28 May and 19 June 1986. The installation of the production ESSS and four external fuel tanks increased the drag of the normal utility configured UH-60A by approximately 13.5 square feet of equivalent flat plate area. This represents a drag reduction of approximately 4.5 square feet for the production ESSS from the prototype ESSS previously tested. The takeoff characteristics were similar to a normal

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: SHEILA R. LEWIS

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22c. OFFICE SYMBOL: SAVTE-PR

DD Form 1473, JUN 86 — Previous editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Block No. 19

utility configured UH-60A and remain a shortcoming. Ground taxi characteristics of the UH-60A at gross weights above 23,000 pounds and at a forward center of gravity were unusual in that precise flight control positioning, concentrated pilot effort and high workload was required during these operations. The ground taxi characteristics are a shortcoming, however, they are adequate for the self-deployment mission.

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INTRODUCTION

BACKGROUND

1. The External Stores Support System (ESSS) was procured by the US Army to fulfill the self-deployment requirement described in the Material Need Document (ref 1, app A) for the UH-60A helicopter. Sikorsky Aircraft Division of United Technologies, who manufactures the UH-60A and ESSS, claimed a drag reduction for the production ESSS over the prototype system. Separately, the US Army desired to ascertain the effect on the self-deployment capability of the UH-60A if the General Electric (GE) T700-GE-700 turboshaft engines were replaced with GE T700-GE-701 engines. To determine if the UH-60A still met the self-deployment requirement with these changes, the US Army Aviation Systems Command (AVSCOM) tasked the US Army Aviation Engineering Flight Activity (USAAEFA) (ref 2, app A) in January 1986 to plan, conduct and report on level flight performance testing of the UH-60A helicopter equipped with a production ESSS and four external fuel tanks.

TEST OBJECTIVE

2. The objective of this evaluation was to obtain level flight performance data for use by AVSCOM to determine if the UH-60A with the production ESSS installed and proposed engine change meets the self-deployment requirement.

DESCRIPTION

3. The test helicopter, a UH-60A Black Hawk, US Army S/N 82-23748, was configured with a production ESSS, two 450-gallon fuel tanks mounted at the inboard store stations, and two preproduction 230-gallon fuel tanks at the outboard stations (photo 1). The ESSS for the Black Hawk consists of airframe fixed provisions and the external stores subsystem. The external stores subsystem is comprised of a horizontal stores support, two diagonal support struts, and two vertical stores pylons for each side of the aircraft. The pylons are designed to accommodate a variety of stores. All store stations permit jettison of stores. The ESSS fuel transfer system was not completely installed in the test aircraft. A description of the standard UH-60A Black Hawk can be found in the operator's manual (ref 3, app A) and a more detailed description of the ESSS and external fuel tanks is included in appendix B.

Photo 1. UH-60A in the ESSS with Four Tanks Configuration

TEST SCOPE

4. The level flight performance tests were conducted at Edwards AFB (elevation 2302 feet) and Bakersfield (488 feet), California. A total of 12 flights were conducted between 28 May and 19 June 1986 for a total of 13.9 productive flight hours. All test flights were conducted in the production ESSS with four tanks configuration. Flight restrictions and operating limitations observed throughout the evaluation are contained in the operator's manual (ref 3, app A) and airworthiness release issued by AVSCOM (ref 4). Testing was conducted in accordance with the test plan (ref 5) at the conditions shown in table 1.

TEST METHODOLOGY

5. The flight test data were recorded by hand from test instrumentation displayed in the cockpit, by on-board magnetic tape recording equipment and via telemetry to the Real Time Data Acquisition and Processing System. A detailed listing of test instrumentation is contained in appendix C. Airspeed calibration data was supplemented by test data from a previous USAAEFA evaluation (ref 6, app A). Flight test techniques and data reduction procedures are described in appendix D.

Table 1. Level Flight Performance Test Conditions[1]

Gross Weight (lb)	Longitudinal Center of Gravity (FS)	Pressure Altitude (ft)	True Airspeed Range (kt)	Remarks
15,200 16,040 17,480 19,260	350.0[2]	7530 9350 10,150 10,380	42 to 152 45 to 149 45 to 145 47 to 128	Base line
18,060 17,440	341.8 357.7	9970[2]	42 to 135 46 to 144	Longitudinal center of gravity effect
21,140 23,560	342.7[2]	5080 2150	42 to 140 39 to 133	Dimensional flight conditions effect
17,080 18,920	350.2[2]	10,450[2]	123 111	Sideslip effect

NOTES:

[1]Tests were conducted at a referred rotor speed of 258 rpm, at a mid lateral center of gravity in the ESSS with four tanks configuration, and with the automatic flight control systems ON.

[2]Values represent average test conditions for appropriate table entry.

RESULTS AND DISCUSSION

GENERAL

6. The level flight performance evaluation of the UH-60A helicopter with the production ESSS and production ferry tanks installed was conducted at Edwards AFB, (2302 feet) and Bakersfield (488 feet), California. The power required for level flight was determined for this configuration for use by AVSCOM to calculate the ferry range and fuel reserves for the self-deployment mission. The data were obtained and analyzed using ball-centered flight as the trim condition at a referred rotor speed of 258 revolutions per minute. The installation of the production ESSS and four external fuel tanks for the self-deployment ferry mission increased the drag of the normal utility configured UH-60A by approximately 13.5 square feet of equivalent flat plate area. This represents a drag reduction of approximately 4.5 square feet from the prototype ESSS configuration. The takeoff characteristics were similar to a normal utility configured UH-60A and remain a shortcoming. Ground taxi characteristics of the UH-60A at gross weights above 23,000 pounds and forward cg were unusual, required high pilot workload and are a shortcoming.

LEVEL FLIGHT PERFORMANCE

General

7. Level flight performance tests were conducted at the test conditions in table 1 to determine the power required for the UH-60A equipped with a production ESSS and four external fuel tanks. Level flight power required test results are presented in figures 1 through 11, appendix E. Techniques used in analyzing the performance data are described in appendix D. The data were corrected for estimated drag of external test instrumentation and the electrical load used by the test instrumentation. Data from test flights at various aircraft longitudinal cg's, dimensional flight conditions, and sideslip angles were compared to the base line level flight performance data to determine the effects on power required.

Base Line

8. The test conditions for the base line level flight performance tests (figs. 3 through 6, app E) were selected to minimize dimensional flight parameter variations. Previous test results (ref 7, app A) showed an unresolved difference in power required at the same true airspeed and thrust coefficient, but different gross weight and altitude combinations. The four test flights were conducted at pressure altitudes near 10,000 feet. The base line data was compared to previous test results for the UH-60A in the

normal utility configuration and with a prototype ESSS installed with four external tanks. The test results of these base line flights when compared to the results reported for the UH-60A with a prototype ESSS installed with four tanks (refs 8 and 9, app A) show an average drag reduction of approximately 4.5 square feet of equivalent flat plate area. Compared to the normal utility configured UH-60A Black Hawk, the installation of the production ESSS with four tanks increased the drag by approximately 13.5 square feet.

Longitudinal Center of Gravity Effect

9. Tests were conducted to determine power required as a function of aircraft longitudinal cg position. Test flights near the expected forward and aft cg limits for self-deployment ferry mission (figs. 7 and 8, app E) were conducted and the data compared to the mission mid cg base line data to determine the change in equivalent flat plate area. Figure A presents the test results in terms of change in equivalent flat plate area from the base line cg. At the expected takeoff cg for the ferry mission, fuselage station (FS) 343, the drag is 5.2 square feet higher than for the mission mid cg (FS 350). A drag reduction of 4.4 square feet was determined for the mission aft cg (FS 358) flight. A large portion of the self-deployment ferry mission is conducted with the aircraft longitudinal cg location forward of the baseline data obtained during this evaluation. Compensation for changes in aircraft cg during the ferry mission should be included in the ferry range determination using the data presented in this report.

Dimensional Flight Conditions Effect

10. Tests were conducted at different dimensional flight conditions (airspeed, gross weight and altitude) that yield the same nondimensional values of main rotor advance ratio and thrust coefficient (figs. 8, 9, and 10, app E). Previous performance tests and data analysis (ref 7, app A) of the UH-60A did not produce consistent results using solely a nondimensional analysis. Stabilator position was determined to be a contributing factor but did not completely explain the phenomenon.

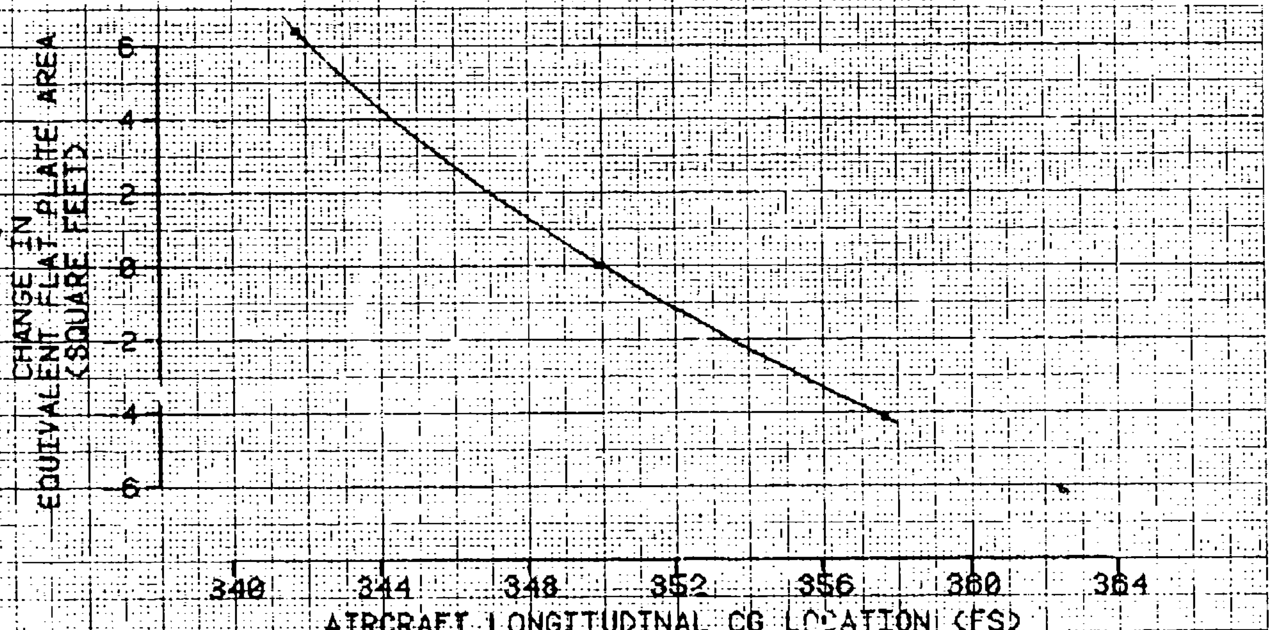
11. The test data obtained during this evaluation initially showed the same inconsistent results. The test airspeed boom system used for data reduction was discovered to be influenced by thrust coefficient (para 5, app D) Until now the position error for the test boom was assumed to be independent of aircraft flight parameters. Once this effect was incorporated into the data reduction method, the nondimensional analysis produced consistent test results at all but the fastest airspeeds. At these airspeeds

FIGURE A

CHANGE IN EQUIVALENT FLAT PLATE AREA
WITH AIRCRAFT LONGITUDINAL CENTER OF GRAVITY

UH-60A USA S/N 82-23748

NOTE: DATA OBTAINED FROM FIGURES 1, 2, 7 AND 8, APP F



and different dimensional conditions, the effect of the stabilator position on power required (para 13, app D) explained most of the remaining power required difference.

Sideslip Effect

12. Limited test data were obtained to determine the effect of sideslip angle on power required (fig. 11, app E). The trend of change in equivalent flat plate area with sideslip was similar to that obtained in previous tests of the normal utility configured UH-60A (ref 7, app A), however, the amount of change in power required as a function of sideslip angle was less.

HANDLING QUALITIES

General

13. Control positions, aircraft attitudes and inherent sideslip angles were obtained in conjunction with the level flight performance tests. Handling qualities of the UH-60A in the test configuration were qualitatively evaluated and found to be similar to the normal utility configured UH-60A. The ground taxi characteristics of the UH-60A at gross weights above 23,000 pounds and forward cg location were unusual, required high pilot workload and are a shortcoming. Takeoff characteristics were similar to a normal utility configured UH-60A and remain a shortcoming. The position error for the ship's airspeed system was increased by approximately two knots due to the installation of the ESSS with four tanks.

Control Positions in Trimmed Level Flight

14. Flight control positions and aircraft attitude data were obtained in conjunction with the level flight performance tests and are presented in figures 13 through 15, appendix E. The data presented in these figures show the effects of thrust coefficient, longitudinal cg location and dimensional flight conditions. The trends of control position with airspeed were similar to those of the UH-60A helicopter in the normal utility configuration.

Ground Taxi Characteristics

15. The ground taxi characteristics of the UH-60A in the ESSS with four tanks configuration were qualitatively evaluated during the performance evaluation. Ground taxi characteristics at gross weights less than 22,000 pounds at all longitudinal cg locations, were similar to a normal utility configured UH-60A.

At gross weights from 23,000 to 24,500 pounds and a forward longitudinal cg location (FS 343) the pilot was required to position the flight controls precisely and concentrate on controlling the aircraft in order to taxi on a level paved surface. To initiate forward aircraft movement, the collective control was raised to approximately mid position and the cyclic controls placed slightly forward of center. Initiating and maintaining forward aircraft movement (taxiing) was difficult and very sensitive to flight control applications. Precise cyclic ($\pm$1/4 inch) and collective ($\pm$1/2 inch) control positioning was required. If too much forward cyclic control was applied with the collective control required to taxi, the aircraft did not move forward but only rotated about the main landing gear lifting the tail wheel off the ground. Small lateral cyclic control application caused the aircraft to bounce on the main landing gear in a lateral rocking motion suggestive of ground resonance. This response was easily stopped by lowering the collective control or centering the cyclic. Applying too much collective control with the cyclic control centered caused the aircraft to leave the ground. When the proper combination and amount of forward cyclic and collective controls were applied, the aircraft moved forward at the pace of a slow walk. This speed could not be changed with any control application. Turns while taxiing were accomplished by small ($\pm$1/4 inch) lateral cyclic and pedal ($\pm$1/2 inch) control movements. These unusual ground taxi characteristics are not exhibited by the UH-60A when operated within its normal gross weight and cg limitations. Ground taxi characteristics that require high pilot workload at gross weights above 23,000 pounds and forward cg are a shortcoming, but are adequate for the intended self-deployment mission. The following note should be incorporated into the UH-60A operator's manual.

NOTE

> Ground taxiing the aircraft in the ESSS with four tanks configuration above 23,000 pounds and a forward longitudinal cg location, requires precise control applications to initiate and maintain forward movement. With sufficient collective control applied, too much forward cyclic control application causes the tail wheel to lift off the ground and any lateral cyclic control application causes the aircraft to bounce on the main landing gear in a lateral rocking motion. Too much collective control application results in the aircraft lifting off the ground.

Takeoff and Landing Characteristics

16. The takeoff and landing characteristics of the UH-60A in the ESSS with four tanks configuration were qualitatively evaluated during the performance evaluation. Normal takeoffs from and landings to a hover were similar to a UH-60A in the normal utility configuration at similar gross weights and longitudinal cgs. Takeoff at 24,500 pounds gross weight (820 feet density altitude and forward longitudinal cg location, FS 343) was accomplished from a 3-foot hover using the level acceleration technique. This technique was used since a normal takeoff profile (accelerate and climb) was not possible because of the gross weight, altitude and power available. Approximately 98% engine torque was required to hover at these conditions. The aircraft accelerated forward slowly after forward cyclic and increased collective controls were applied. The pilot was required to monitor engine torque and rotor speed closely while maintaining the 3-foot wheel height during the acceleration portion of the takeoff. The aircraft exhibited a noticeable 5 to 7 degree nose down pitch attitude until reaching approximately 40 knots indicated airspeed. At approximately 45 knots, a pitch over tendency occurred. Up to 90% aft longitudinal cyclic control (10% aft longitudinal control remaining) was required to arrest the pitch over. In addition, small (±1/8 inch) frequent cyclic and moderate (±1/2 inch) occasional directional control movements were required throughout the takeoff. These aircraft characteristics and control requirements increased the pilot workload and were objectionable (HQRS 5) (fig. 1, app D). Similar characteristics for normal takeoffs were described for a normal utility configured UH-60A (ref 10, app A) and reported as a shortcoming. The objectionable takeoff characteristics for this UH-60A in the ESSS with four tanks configuration are similar to a normal utility configured UH-60A and remain a shortcoming.

INHERENT SIDESLIP CHARACTERISTICS

17. The inherent sideslip angles were measured and recorded during all test flights. Like the previous test results (refs 7, 8, and 9, app A), the inherent sideslip varied with thrust coefficient and airspeed. No consistent trend with longitudinal cg location or dimensional flight condition was determined. The data from all the test flights were grouped according to thrust coefficient and faired to determine the inherent sideslip for the UH-60A in the ESSS with four tanks configuration (fig. 12, app E). Compared to the UH-60A in the normal utility configuration, the inherent sideslip was 2 to 3 degrees further left. This characteristic agrees with results reported previously on the UH-60A with a prototype ESSS installed (refs 8 and 9, app A).

PITOT-STATIC SYSTEM CALIBRATION

18. Airspeed calibration tests were conducted to determine the position error of the airspeed system for the UH-60A in the ESSS with four tanks configuration. Two flights were conducted using a pace aircraft with a calibrated pitot-static system installed. The position error determined from these flights is presented in figure 16, appendix E. Also presented in this figure are data from a previous USAAEFA test (ref 6, app A). Compensating for the longitudinal cg difference between the data sets (+1.0 knot), the position error for the UH-60A in the ESSS with four tanks configuration is approximately 2 knots higher at 110 knots indicated airspeed than the normal utility configured Black Hawk. This airspeed is near the long-range cruise airspeed for the ferry mission. This airspeed position error should be incorporated in the performance planning section of the UH-60A operator's manual for the ESSS with four tanks configured Black Hawk.

19. A test airspeed boom was mounted at the nose of the test aircraft and is described in paragraph 3, appendix C. The airspeed boom was used as a speed reference in order to determine the effects of thrust coefficient and aircraft longitudinal cg on the ship's airspeed system position error. The data to determine these effects was obtained in conjunction with the level flight performance tests and are presented in figures 17 and 18, appendix E. A trend of increasing position error with increasing thrust coefficient, approximately 1.5 knots, was determined for the thrust coefficient range tested. Changing the aircraft longitudinal cg location from FS 358 to FS 343 increased the position error approximately 3 knots over the entire airspeed range.

CONCLUSIONS

GENERAL

20. Based on this evaluation, the following conclusions were reached about the UH-60A Black Hawk with the production ESSS installed with two 450-gallon tanks and two preproduction 230-gallon tanks mounted at the inboard and outboard pylons, respectively.

a. The production ESSS with four tanks configuration was determined to have approximately 4.5 square feet less drag than the prototype ESSS with four tank configuration previously tested (para 8).

b. The addition of the production ESSS with four tanks to the UH-60A Black Hawk increases the drag by approximately 13.5 square feet (para 8).

c. The drag of the UH-60A with the production ESSS and four tanks varies 9.6 square feet of equivalent flat plate area with aircraft longitudinal cg variation from FS 343 to FS 358 (para 9).

d. The effect of sideslip on power required was less than that for a normal utility configured UH-60A (para 12).

e. The ship system airspeed position error varied with aircraft longitudinal cg location and thrust coefficient (para 19).

SHORTCOMINGS

21. The following shortcomings were identified.

a. The ground taxi characteristics of this UH-60A at gross weights above 23,000 pounds and forward cg location that require high pilot workload are a shortcoming, but adequate for the intended self-deployment mission (para 15).

b. The takeoff characteristics of the UH-60A in the ESSS with four tanks configuration are similar to a normal utility configured UH-60A and remain a shortcoming (para 16).

RECOMMENDATIONS

22. The following recommendations are made:

a. The power required data presented in this report should be used to determine the ferry range and fuel reserve of a UH-60A with a production ESSS installed with two 450-gallon and two 230-gallon external fuel tanks at the inboard and outboard pylon stations, respectively (paras 8 through 12).

b. The following NOTE should be placed in the operator's manual (para 15).

NOTE

> Ground taxiing the aircraft in the ESSS with four tanks configuration above 23,000 pounds and a forward longitudinal cg location, requires precise control applications to initiate and maintain forward movement. With sufficient collective control applied, too much forward cyclic control application causes the tail wheel to lift off the ground and any lateral cyclic control application causes the aircraft to bounce on the main landing gear in a lateral rocking motion. Too much collective control application results in the aircraft lifting off the ground.

c. The ship system airspeed position error determined for the ESSS with four tanks configuration should be included in the performance planning section of the operator's manual (paras 18 and 19).

APPENDIX A. REFERENCES

1. Document, TRADOC, ATCD-B, UH-60A Black Hawk Material Need, Production, Updated (MN)(P)(U), Action Control Number 10705, August 1979 with change dated 13 December 1980.

2. Letter, AVSCOM, AMSAV-8, 24 January 1986, subject: UH-60A/ESSS Production Configuration Level Flight Power Required Determination for the Ferry Mission, USAAEFA Project No. 86-01. (Test Request)

3. Technical Manual, TM55-1520-237-10, *Operator's Manual, UH-60A Helicopter,* Headquarters Department of the Army, 21 May 1979 with change 35 dated 24 March 1986.

4. Letter, AVSCOM, AMSAV-E, 22 May 1986, subject: Airworthiness Release of UH-60A Black Hawk Helicopter S/N 82-23798 to Conduct a Level Flight Performance Evaluation of the UH-60A with the Production External Stores Support System and Ferry Tanks Installed, USAAEFA Project No. 86-01

5. Test Plan, USAAEFA Project No. 86-01, *Level Flight Performance Evaluation of the UH-60A Helicopter with the Production External Stores Support System and Ferry Tanks Installed,* 14 May 1986.

6. Final Report, USAAEFA Project No. 84-28, *Flight Evaluation of the UH-60A Helicopter with the Pitch Bias Actuator (PBA) Locked and Centered,* unpublished.

7. Final Report, USAAEFA Project No. 83-24, *Airworthiness and Flight Characteristics Test of a Sixth Year Production UH-60A,* Unpublished.

8. Final Report, USAAEFA Project No. 82-14, *Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System (ESSS),* March 1983.

9. Final Report, USAAEFA Project No. 82-15, *Airworthiness and Flight Characteristics Test of the UH-60A Configured with the Prototype External Stores Support System (ESSS),* December 1983.

10. Final Report, USAAEFA Project No. 82-09, *Preliminary Airworthiness Evaluation of UH-60A with an Improved Airspeed System,* April 1983.

APPENDIX B. DESCRIPTION

GENERAL

1. The UH-60A is a twin engine, single main rotor helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20 degrees upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The maximum gross weight was increased to 24,500 pounds for the self-deployment ferry mission. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 revolutions per minute) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 shp. The aircraft also has an automatic flight control system and a command instrument system. The test helicopter, UH-60A US Army S/N 82-23748, was manufactured by Sikorsky Aircraft Division of United Technologies Corporation, and is from the sixth year production lot. The addition of a nose-mounted airspeed boom is the main external difference between the test aircraft and a standard sixth year production UH-60A helicopter with the External Stores Support System installed. The external configuration of the test aircraft (photos 1 through 8) was the same for all test flights. The fuel transfer components of the external fuel system were not completely installed in the test aircraft. Fuel was not capable of being transferred from the external fuel tanks.

EXTERNAL STORES SUPPORT SYSTEM

2. The External Stores Support System (ESSS) consists of the airframe fixed provisions and the removable external stores subsystem. The ESSS was designed to enable the UH-60A to carry external stores such as auxiliary fuel tanks or various weapons systems.

3. The airframe fixed provisions (fig. 1) are the fuselage attachment structure required for the installation of the removable external stores subsystem. The removable external stores subsystem consists of the horizontal store support which is a composite boxed I-beam structure, the support struts (two on each wing) and the vertical stores pylons (two on each wing) all of which are enclosed with thin aluminum fairings. Ejector racks were mounted on the vertical stores pylons at a 4° nose up angle

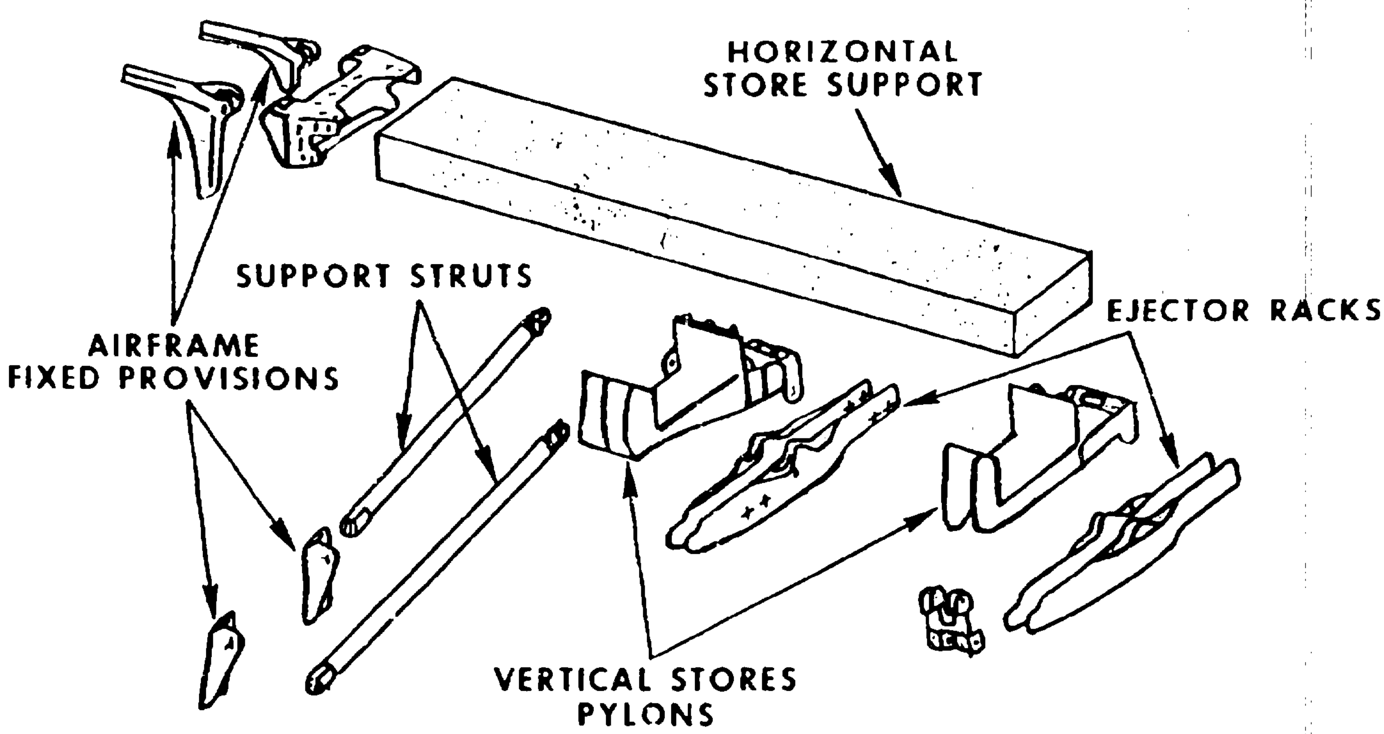


Figure 1. ESSS Structural Components

Photo 1. UH-60A in the ESSS with Four Tanks Configuration - Front View

Photo 2. UH-60A in the ESSS with Four Tanks Configuration - Left Front View

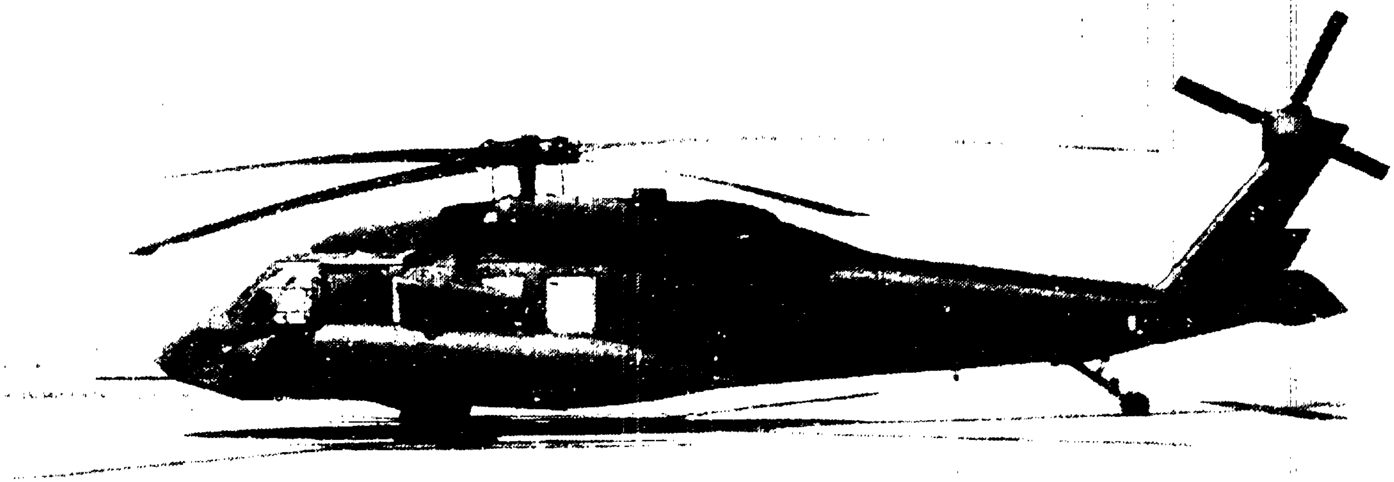


Photo 3. UH-60A in the ESSS with Four Tanks Configuration - Left Side View

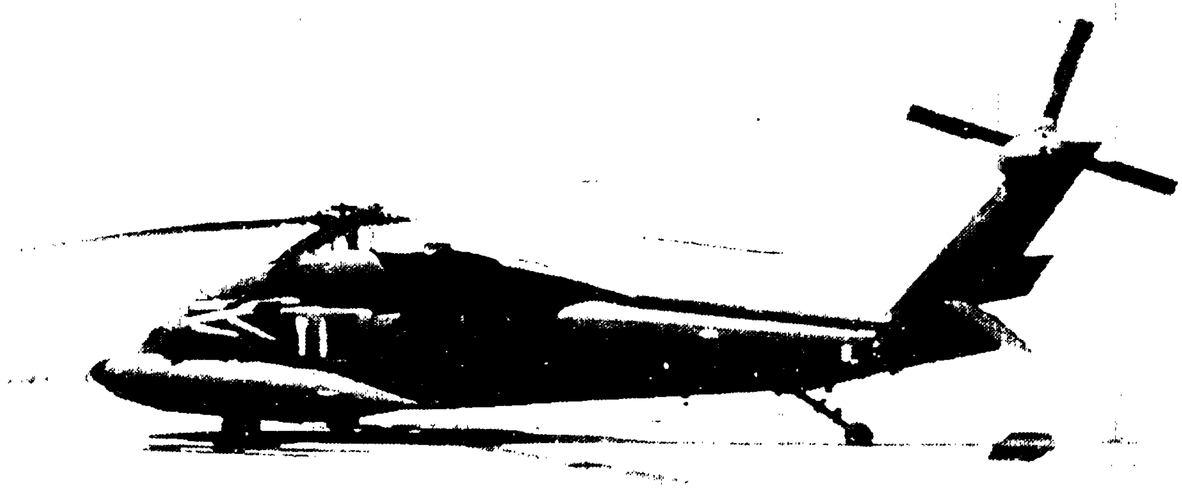


Photo 4. UH-60A in the ESSS with Four Tanks Configuration - Left Rear Quartering View

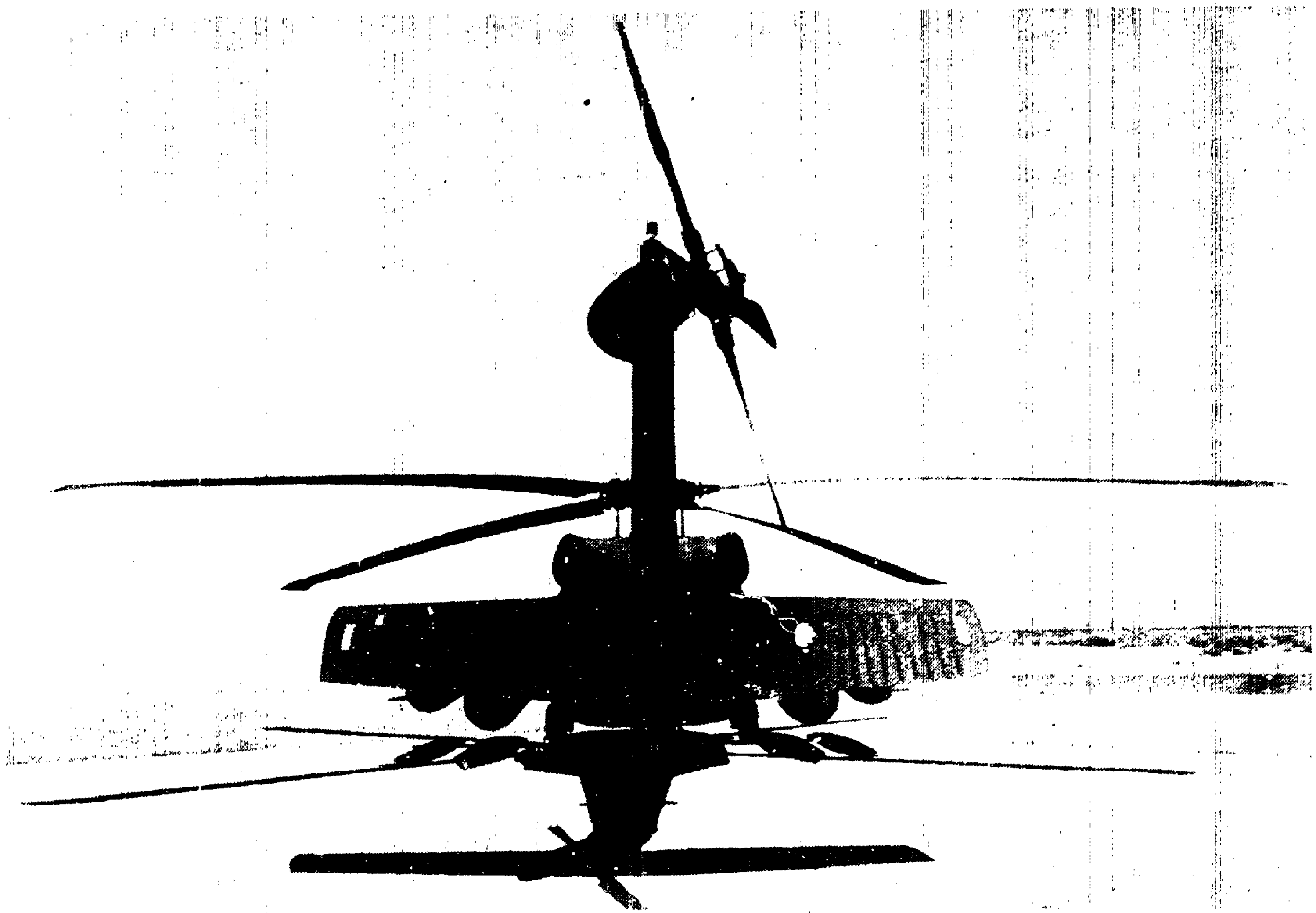


Photo 5. UH-60A in the ESSS with Four Tanks Configuration - Rear View

Photo 6. UH-60A in the ESSS with Four Tanks Configuration - Right Rear Quartering View

Photo 7. UH-60A in the ESSS with Four Tanks Configuration - Right Side View

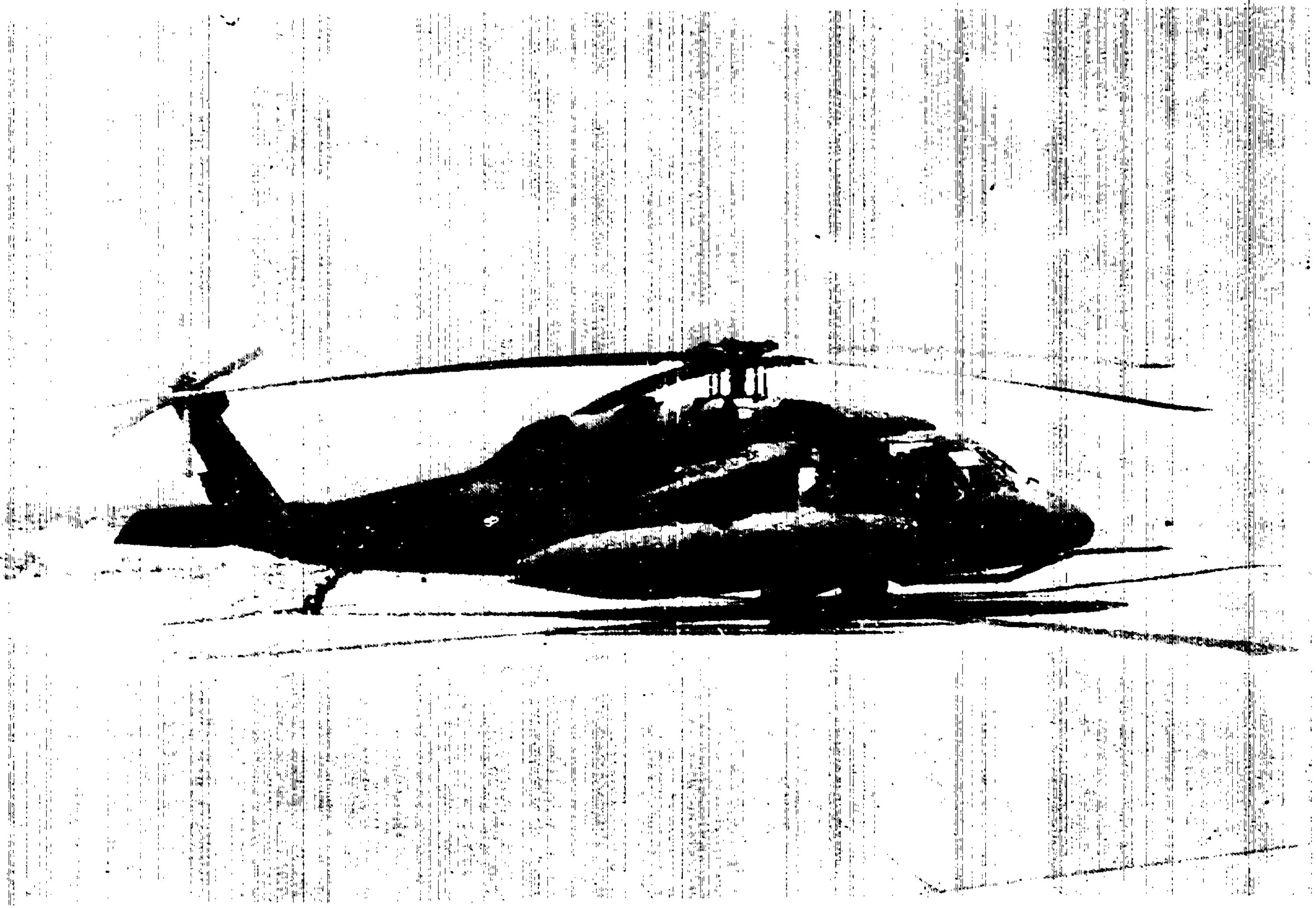


Photo 8. UH-60A in the ESSS with Four Tanks Configuration - Right Front Quartering View

with reference to the aircraft waterline. For this test, Model MAU-40 ejector racks were mounted on the inboard pylons and BRU-22A ejector racks on the outboard pylons.

4. The 230-gallon fuel tanks mounted at the outboard stores station were preproduction tanks manufactured by Tre-Fibertek. Fiber Technology Corporation MFG Part No. 230SFT001-11, and were constructed out of composite materials. The tanks were filled, as required, with 230 gallons of ordinary water, and used as ballast for the tests. The 450-gallon fuel tanks were manufactured by Sargent Fletcher Fuel Tanks, MFG Part No. 72429/29-450-48295 and remained empty for the tests. All four tanks were finished with exterior top coat, MIL-L46-159 olive drab acrylic lacquer No. 34087.

EXTERNAL MODIFICATIONS

5. Several external modifications were made to the test aircraft for instrumentation. These modifications were not part of the standard UH-60A or the ESSS. Drag estimates for these items totaled 0.883 ft^2 of equivalent flat plate area. Each item is listed below:

Airspeed boom
Ambient air temperature sensor
Telemetry antenna (2): one on the underside of the tail boom near the forward tail wheel strut attachment point, the other to the right of the left main wheel strut attachment point.

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by the US Army Aviation Engineering Flight Activity. A test boom, with a swiveling pitot-static tube and angle-of-attack and sideslip vanes, was installed at the nose of the aircraft. Two telemetry antennae were mounted to the underside of the fuselage and tail boom. All other instrumentation was installed inside the test aircraft. Data were obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Airspeed (ship)*
Altitude (boom)
Altitude (ship)*
Rate of climb*
Rotor speed (sensitive-digital)
Engine torque* **
Turbine gas temperature* **
Power turbine speed (N_p)* **
Gas producer speed (N_g)* **
Control position
    Longitudinal
    Lateral
    Directional
    Collective
Horizontal stabilator position*
Center of gravity (cg) lateral acceleration (sensitive)
Angle of sideslip

Copilot Panel

Event switch
Airspeed*
Altitude*
Rotor speed*
Engine torque* **
Ballast cart control
Ballast cart position
Fuel remaining* **

*Ship's system/not calibrated
**Both engines

Engineer Panel

Pressure altitude
Ambient pressure
Engine fuel flow**
Engine fuel used**
APU fuel used
Total air temperature
Instrumentation controls
Time code display
Run number
Event switch

2. Data parameters recorded on board the aircraft and available for telemetry include the following:

Digital (PCM) Data Parameters

Airspeed (boom)
Altitude (boom)
Airspeed (ship's)
Altitude (ship's)
Total air temperature
Rotor Speed
Gas generator speed**
Power turbine speed**
Engine fuel flow**
Engine fuel temperature**
Engine output shaft torque**
Turbine gas temperature**
APU fuel used
CG lateral acceleration (sensitive)
Stabilator position
Movable ballast location
Control position
    Longitudinal
    Lateral
    Directional
    Collective
Attitude
    Pitch
    Roll
    Heading

*Ship's system/not calibrated
**Both engines

Tail rotor impressed pitch (blade angle at 0.75 blade span)
Angle of sideslip
Angle of attack
Time of day
Run number
Pilot event switch
Engineer event

TEST BOOM AIRSPEED SYSTEM

3. The test boom airspeed system mounted at the nose of the test aircraft provided measurements of airspeed and altitude. Sensors for angles of attack and sideslip were also mounted on the test boom (photo 1). The tip of the swiveling pitot-static tube was 67 inches forward of the nose of the aircraft (FS 97), 25.7 inches to the right of the aircraft reference butt line (BL 25.7) and 7 inches below the forward avionics bay floor, WL 208. The "bent-up" shape provided ground clearance for aircraft operation at heavy gross weights and forward longitudinal center of gravity locations.

AIRSPEED CALIBRATION

4. The test boom airspeed system along with the ship's standard systems were calibrated in level flight. A calibrated T-28 pace aircraft was used to determine the position error. Data obtained from a previous USAAEFA evaluation (ref 6, app A) using the same aircraft and boom airspeed were used to corroborate test data. The position error of the boom airspeed system is presented in figures 1 through 3.

ENGINE CALIBRATION

5. Each engine torque sensor system was specially calibrated in a test cell by the engine manufacturer, General Electric. Figures 4 and 5 present the calibrations used to determine engine output power.

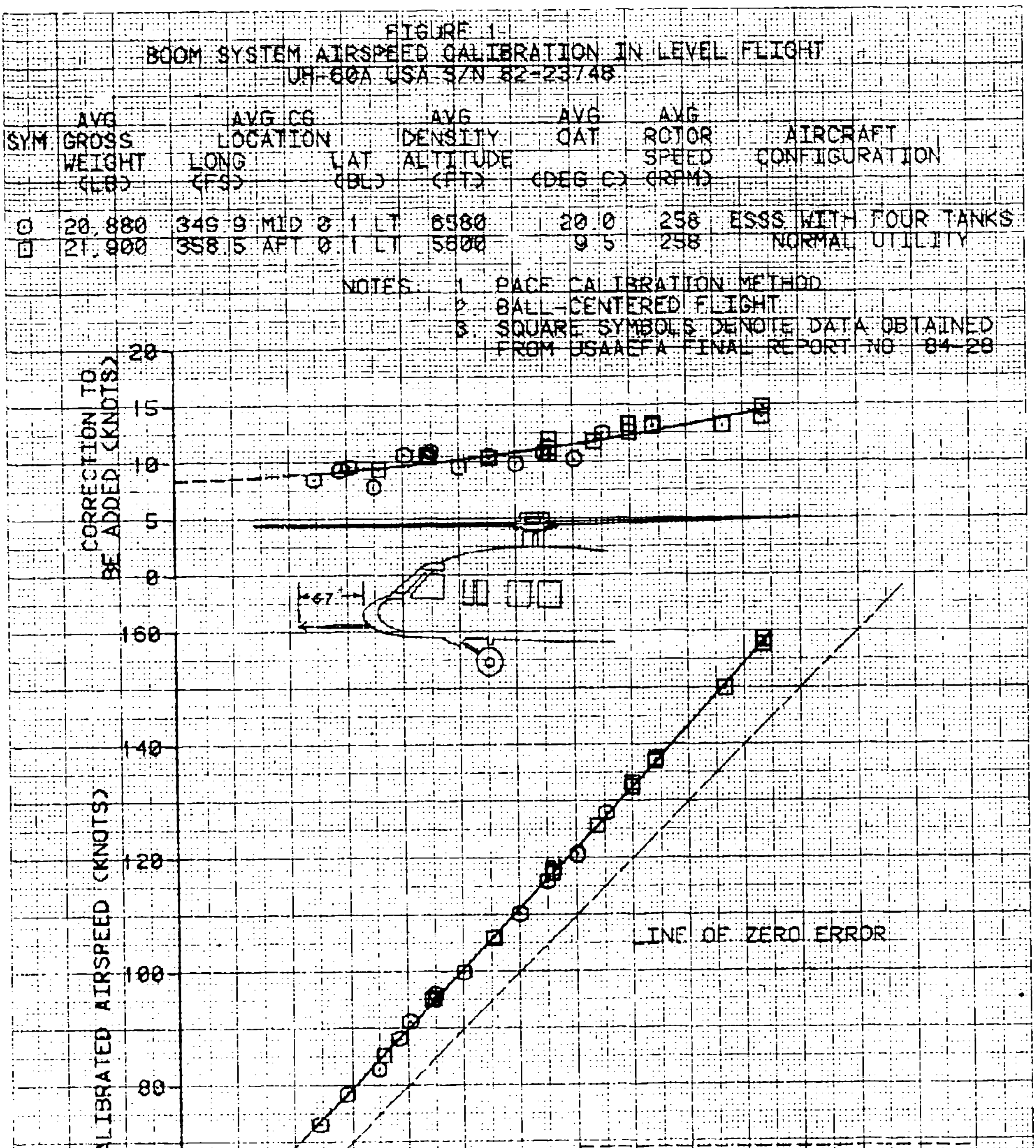


FIGURE 1
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748
SYM
AVG GROSS WEIGHT (LB)
AVG CG LOCATION
LONG (FS)
LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG ROTOR SPEED (RPM)
AIRCRAFT CONFIGURATION
20,880 349.9 MID 0.1 LT 6580 20.0 258 ESSS WITH FOUR TANKS
21,900 358.5 AFT 0.1 LT 5600 9.5 258 NORMAL UTILITY
NOTES: 1. PACE CALIBRATION METHOD
2. BALL-CENTERED FLIGHT
3. SQUARE SYMBOLS DENOTE DATA OBTAINED FROM USAAEFA FINAL REPORT NO. 84-28
CORRECTION TO BE ADDED (KNOTS)
20
15
10
5
0
67
160
140
120
100
80
60
40
CALIBRATED AIRSPEED (KNOTS)
LINE OF ZERO ERROR
NOT FOR HANDBOOK USE
40
60
80
100
120
140
160
180
INDICATED AIRSPEED (KNOTS)

FIGURE 2
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AIRCRAFT CONFIGURATION
○	16,920	349.8 MID	0.1 LT	6180	19.0	258	ESSS WITH FOUR TANKS
□	16,400	361.0 AFT	0.2 RT	5100	7.0	257	NORMAL UTILITY

NOTES: 1. PACE CALIBRATION METHOD
2. BALL-CENTERED FLIGHT
3. SQUARE SYMBOLS DENOTE DATA OBTAINED FROM USAAEFA FINAL REPORT NO. 84-28

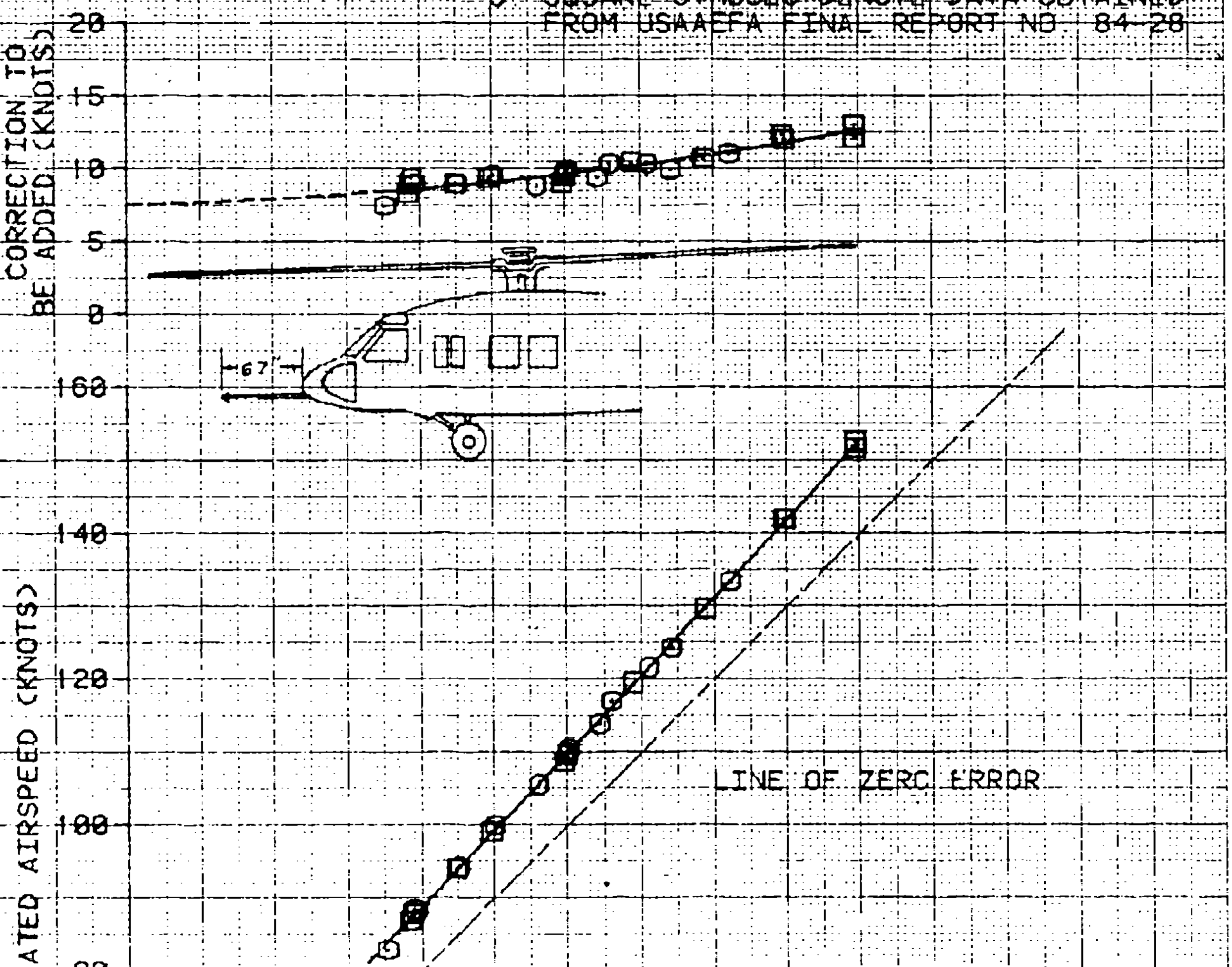
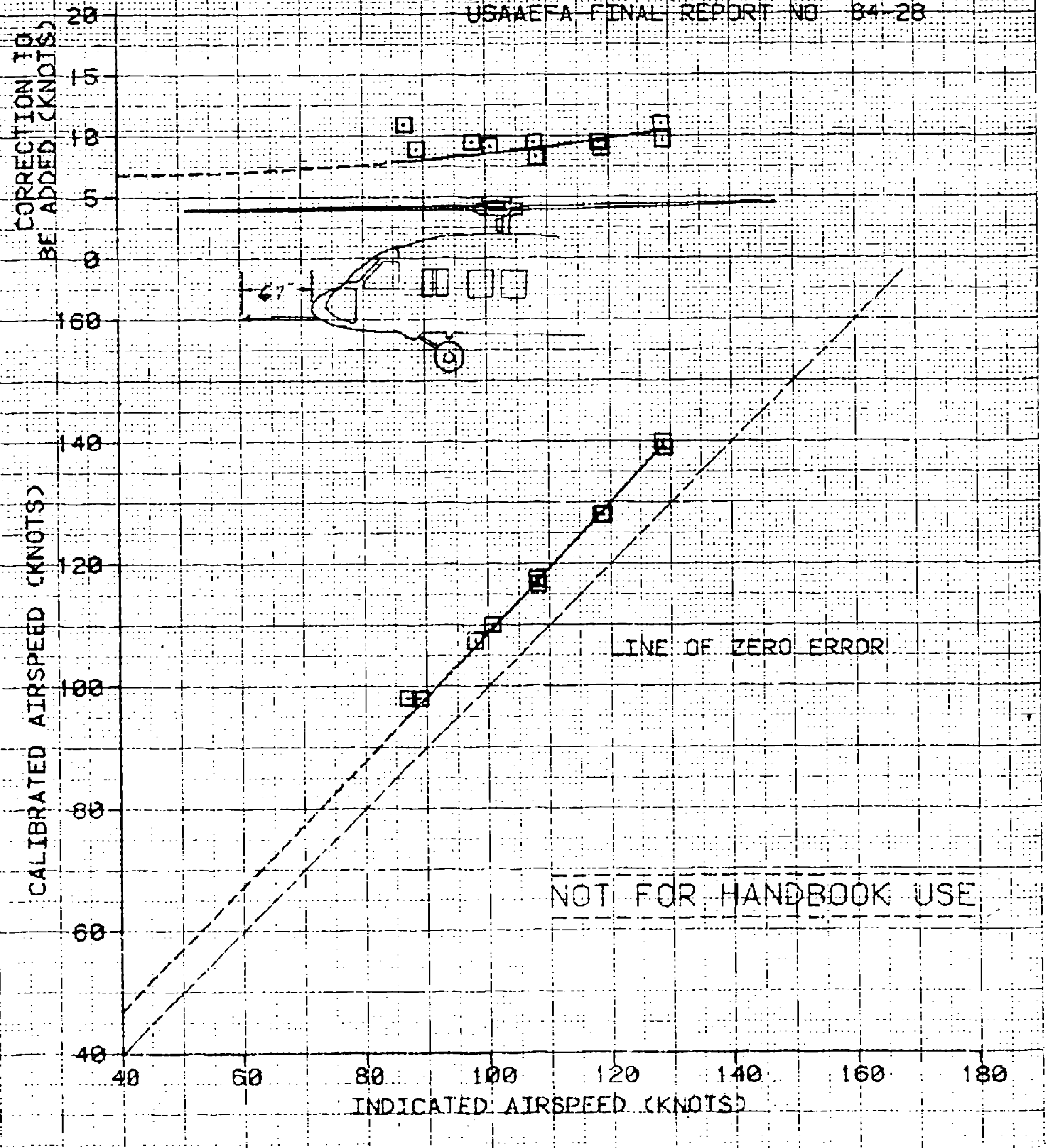


FIGURE 3
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AIRCRAFT CONFIGURATION
13,650	361.1 AFT	0.2 RT	5200	16.5	258	NORMAL UTILITY

NOTES: 1. PACE CALIBRATION METHOD
2. BALL-CENTERED FLIGHT
3. DATA OBTAINED FROM USAAEFA FINAL REPORT NO. 84-28



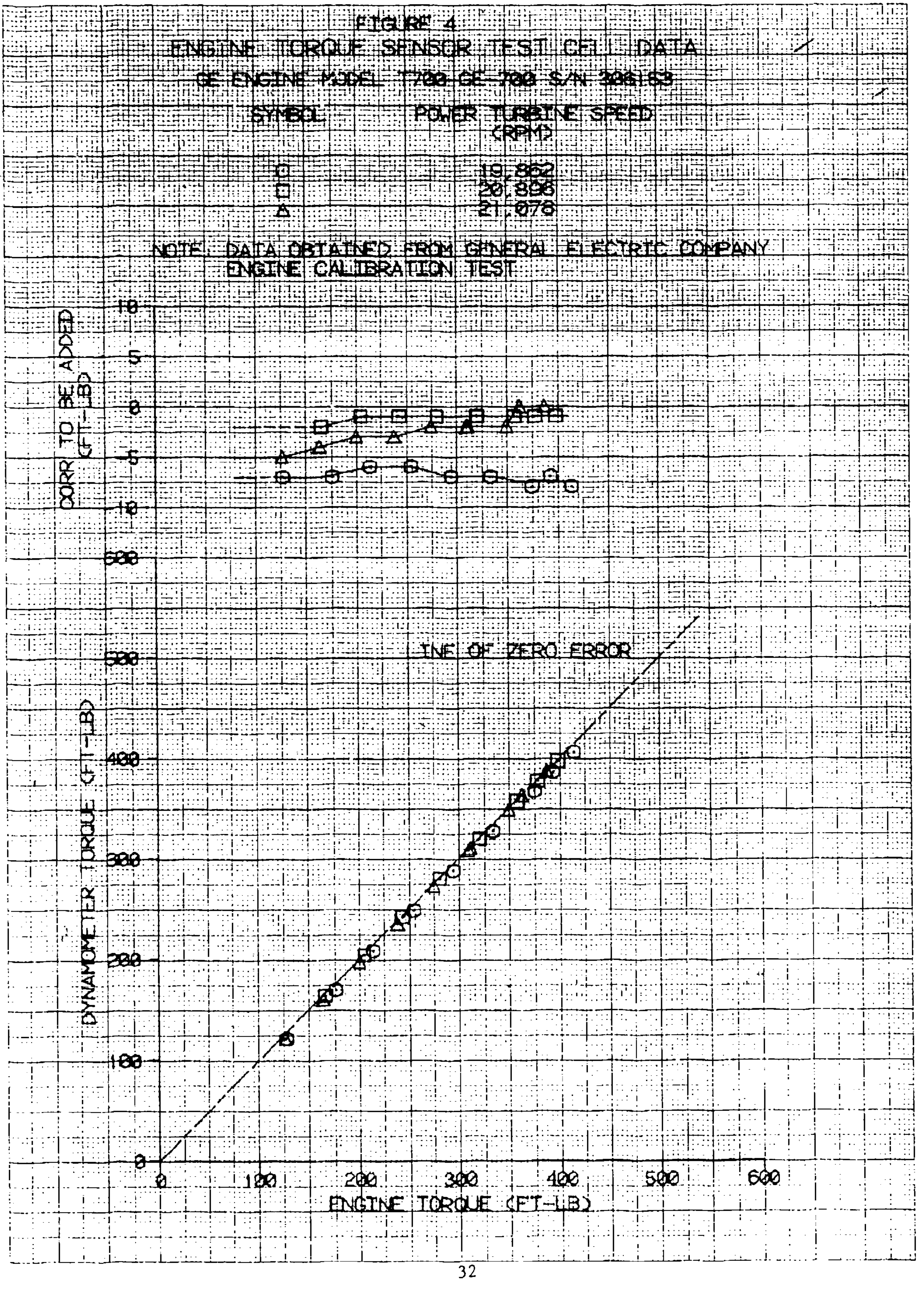


FIGURE 4
ENGINE TORQUE SENSOR TEST CELL DATA
GE ENGINE MODEL T700-GE-700 S/N
SYMBOL
POWER TURBINE SPEED (RPM)
19,862
20,896
21,078
NOTE: DATA OBTAINED FROM GENERAL ELECTRIC COMPANY ENGINE CALIBRATION TEST
CORR TO BE ADDED (FT-LB)
10
5
0
-5
-10
600
500
400
300
200
100
0
LINE OF ZERO ERROR
DYNAMOMETER TORQUE (FT-LB)
0
100
200
300
400
500
600
ENGINE TORQUE (FT-LB)

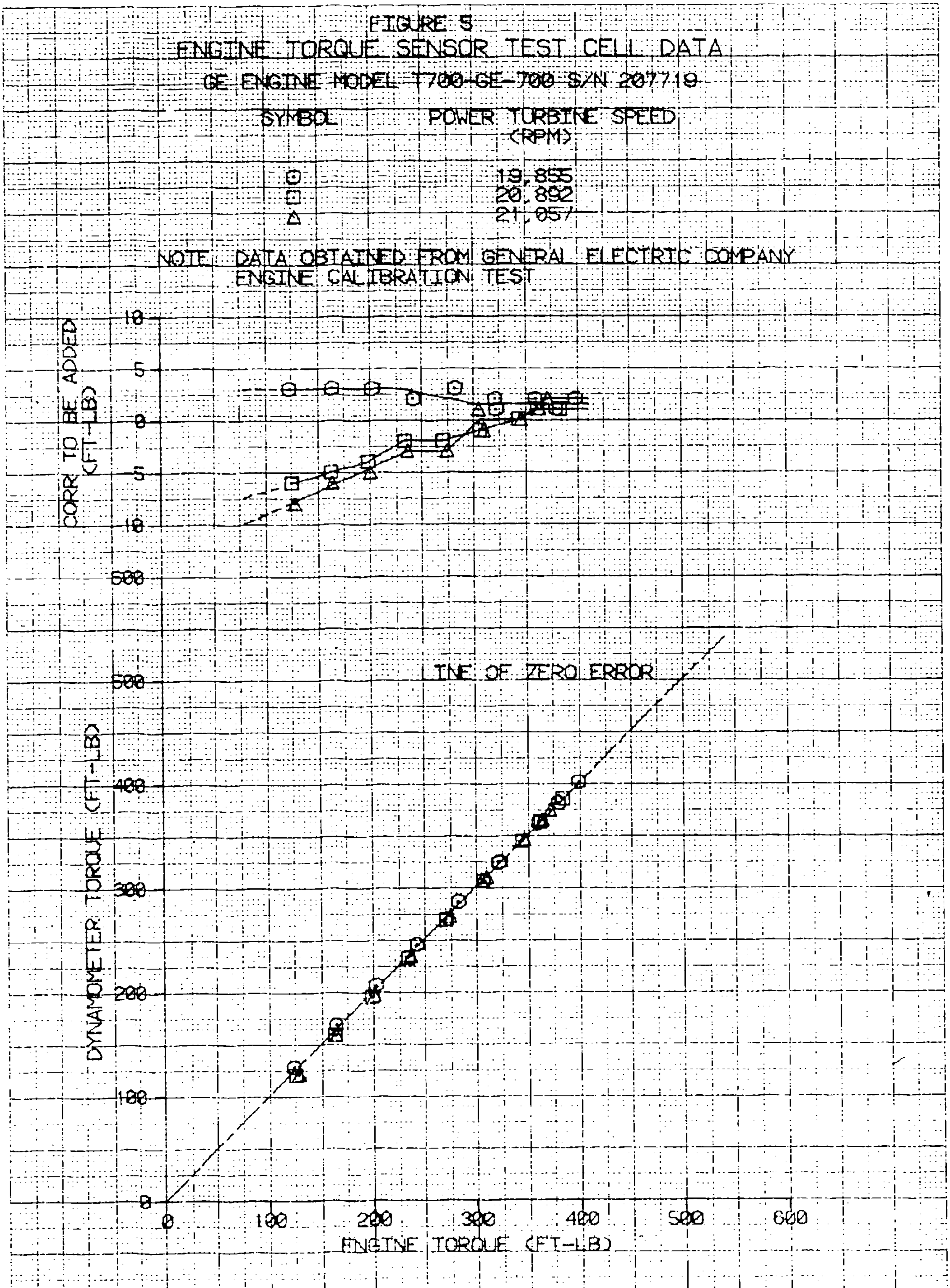


FIGURE 5
ENGINE TORQUE SENSOR TEST CELL DATA

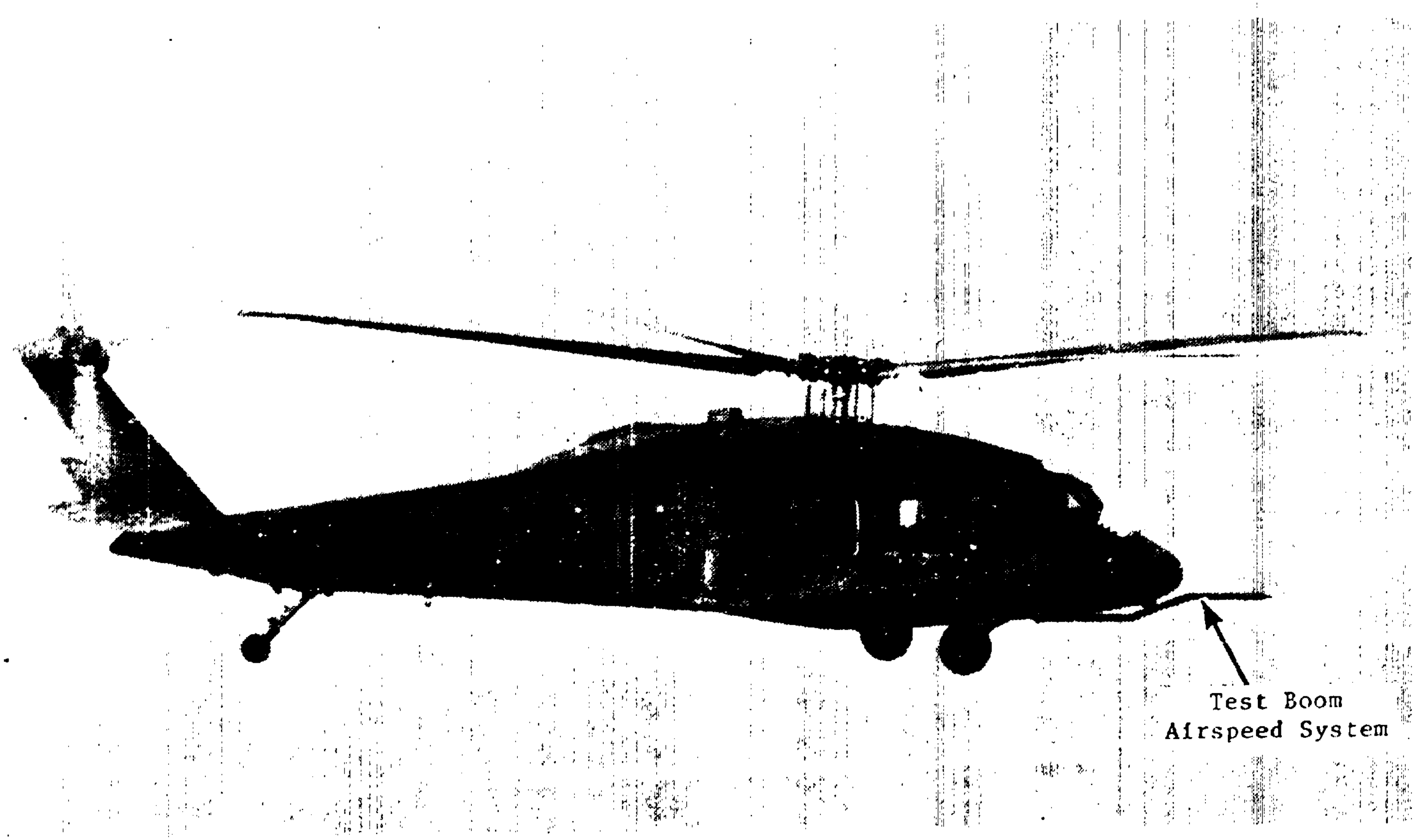


Photo 1. UH-60A in the ESSS with Four Tanks Configuration

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

AIRCRAFT RIGGING

1. A flight controls engineering rigging check was performed on the main and tail rotors during a previous test program conducted by the US Army Aviation Engineering Flight Activity (ref 6, app A). The stabilator control system was also checked to insure compliance with the production stabilator schedule. The rigging complied with the established limits and no changes to the flight controls were made for this test program. The rigging data are presented in table 1.

AIRCRAFT WEIGHT AND BALANCE

2. The test aircraft was weighed initially with the complete instrumentation system and the External Stores Support System (ESSS) with four tanks installed, full oil and all fuel drained, and all ballast and ballast boxes removed. The weight of the aircraft in this configuration was 12,987 pounds with a longitudinal center of gravity (cg) located at fuselage station (FS) 352.2 and lateral cg at butt line (BL) 0.1 left. The installation of the production ESSS increased the empty weight of the aircraft by approximately 1238 pounds. The fuel transfer control panel and fuel transfer lines (components of the ESSS) were not installed for this test.

3. Lead weights secured inside the aircraft and ordinary water in the outboard 230-gallon fuel tanks were used to adjust aircraft gross weight and cg for test purposes. The outboard 230-gallon fuel tanks were either empty or full of water to prevent sloshing and cg shifts during flight. Because of the large gross weight and cg variations used during the evaluation, the aircraft was weighed several times to confirm calculated aircraft weights and cg's. The external aircraft configuration (ESSS with four tanks) was the same for all test flights.

4. The fuel weight for each test flight was determined prior to engine start and after engine shutdown by using external sight gages to determine the volume and measuring the specific weight of the fuel. Except for two flights near 16,000 pounds gross weight, aircraft cg was controlled by a moveable ballast system. The moveable ballast system was a cart (2664 pound capacity) attached to the cabin floor by rails and driven by an electric jack screw. It had a total longitudinal travel of 72.7 inches (FS 301.0 to FS 373.7). The longitudinal cg was allowed to vary ± 2.0 inches for the two level flight performance test flights for which the cg control system was not installed.

Table 1. Main and Tail Rotor Rigging Information

Main Rotor Rigging

Flight Control Position				Swashplate Tilt (Degrees)		Collective[1] Blade Pitch at the Root (degrees)
Collective	Longitudinal	Lateral	Pedal	Long	Lat	
Low	*[2]	*	*	-8.7	-2.1	9.6
High	*	*	*	-4.2	-3.3	24.3
Low	AFT	LT	*	-9.4	-7.4	8.8
High	AFT	LT	*	-9.2	-7.6	24.0
Low	FWD	RT	*	11.0	7.2	9.3
High	FWD	RT	*	17.3	6.5	23.4
High	AFT	LT	LT	-11.3	-7.7	23.6
Mid	AFT	LT	*	-11.7	-7.5	16.6
Mid	FWD	RT	*	15.6	6.2	15.5
Mid	*	*	*	-7.4	-2.6	17.0

Tail Rotor Rigging

Flight Control Position		Tail Rotor Collective Blade Pitch[1] at the Root (Degrees)
Collective	Pedal	
Mid	LT	-23.3
Mid	RT	7.5
Mid	MID	- 7.7
Low	MID	- 0.1
High	MID	-16.2
High	LT	-23.8
High	RT	- 1.8
Low	RT	6.3
Low	LT	-15.7

NOTES:

[1]Average of four blades.
[2]*Indicates appropriate control was pinned at a rigged position.

AIRSPEED CALIBRATION

5. Two flights were conducted during this evaluation to determine the position error of the test airspeed boom system. The data was obtained at two values of thrust coefficient. The position error for the two data sets did not agree. Test data from a previous evaluation of the same UH-60A but in the normal utility configuration (ref 6, app A) were compared to the data obtained for this evaluation (figs. 1 through 3, app C). The same test technique (pace aircraft) and data reduction methods were used. The position error was determined to be a function of thrust coefficient after these data were combined. A linear interpolation with thrust coefficient was used to obtain the position error for data reduction.

PERFORMANCE

General

6. Helicopter performance was generalized through the use of nondimensional coefficients as follows using the 1968 US Standard Atmosphere:

a. Coefficient of Power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \tag{1}$$

b. Coefficient of Thrust (C_T):

$$C_T = \frac{GW}{\rho A(\Omega R)^2} \tag{2}$$

Where:

SHP = Engine output shaft horsepower (total for both engines)

ρ = Ambient air density ($lb\text{-}sec^2/ft^4$) = $\rho_0 \left[\frac{\delta}{\theta}\right]$

ρ_0 = 0.0023769 ($lb\text{-}sec^2/ft^4$)

$$\delta = \text{Pressure ratio} = \frac{P_a}{P_{ao}}$$

P_a = Ambient air pressure (in.-Hg)

P_{ao} = 29.92126 in.-Hg

$$\theta = \text{Temperature ratio} = \frac{\text{OAT} + 273.15}{288.15}$$

OAT = Ambient air temperature (°C)

A = Main rotor disc area = 2262 ft^2

Ω = Main rotor angular velocity (radians/sec)

R = Main rotor radius = 26.833 ft

GW = Gross weight (lb)

$$V_T = \text{True airspeed (kt)} = \frac{V_E}{1.6878\sqrt{\rho/\rho_o}}$$

1.6878 = Conversion factor (ft/sec-kt)

V_E = Equivalent airspeed (ft/sec) =

$$\left[\frac{7(70.7262\ P_a)}{\rho_o}\left[\left(\frac{Q_c}{P_a} + 1\right)^{2/7} - 1\right]\right]^{1/2}$$

70.7262 = Conversion factor (lb/ft^2-in.-Hg)

Q_c = Dynamic pressure (in.-Hg)

P_a = Ambient air pressure (in.-Hg)

At the normal operating rotor speed of 257.9 (100%), the following constants may be used to calculate C_P and C_T:

ΩR = 724.685
$(\Omega R)^2$ = 525,168.152
$(\Omega R)^3$ = 380,581,411.9

7. The engine output shaft torque was determined by use of the engine torque sensor. The power turbine shaft twists as a function of applied torque. A concentric reference shaft is secured by a pin at the front end of the power turbine drive shaft and is free to rotate relative to the power turbine drive shaft at the rear end. The relative rotation is due to transmitted torque, and the resulting phase angle between the reference teeth on the two shafts is picked up by the torque sensor. The torque sensors for engines installed in the aircraft during this evaluation were specially calibrated in a test cell by the engine manufacturer, General Electric. The output from the engine sensor was recorded on the onboard data recording system. The output SHP was determined from the engine's output shaft torque and rotational speed by the following equation.

$$SHP = \frac{Q(N_P)}{5252.113} \tag{4}$$

Where:

Q = Engine output shaft torque (ft-lb)

N_P = Engine output shaft rotational speed (rpm)

5252.113 = Conversion factor (ft-lb-rev/min-SHP)

The output SHP required was assumed to include 13 horsepower for daylight operations of the aircraft electrical system, but was corrected for the effects of test instrumentation installation. A power loss of 1.82 horsepower was used for electrical operation of the instrumentation. Reductions in power required were made for the effect of external instrumentation drag (para 5, app B). This was determined by the following equation.

$$SHP_{instr\ drag} = \frac{\Delta F_e\ (\rho/\rho_o)(V_T)^3}{96254} \tag{5}$$

Where:

ΔF_e = 0.833 ft^2 (estimated)

96254 = Conversion factor (ft^2-kt^3/SHP)

The nominal fuel temperature of 55°C was used in the determination of engine fuel consumption.

Level Flight Performance

General:

8. Each speed power was flown in ball-centered flight by reference to a sensitive lateral accelerometer at a predetermined C_T and referred rotor speed ($N_R/\sqrt{\theta}$). To maintain the ratio of gross weight to pressure ratio constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was decreased as temperature decreased. Power corrections for rate-of-climb and acceleration were determined (when applicable) by the following equations.

$$SHP_{R/C} = -\frac{(R/C_{TL})(GW)}{33{,}000(K_P)} \tag{6}$$

$$SHP_{ACCEL} = -1.6098 \times 10^{-4}\left(\frac{\Delta V}{\Delta t}\right)(V_T)\ (GW) \tag{7}$$

Where:

$$R/C_{TL} = \text{Tapeline rate of climb (ft/min)} = \left(\frac{\Delta Hp}{\Delta t}\right)\frac{(OAT + 273.15)}{(OAT_S + 273.15)}$$

$\frac{\Delta Hp}{\Delta t}$ = Change in pressure altitude per unit time (ft/min)

OAT_S = Standard ambient temperature at pressure altitude where $\frac{\Delta Hp}{\Delta t}$ was measured (°C)

K_P = 0.76 = power correction factor

1.6098×10^{-4} = Conversion factor (SHP-sec/kt^2-lb)

$$\frac{\Delta V}{\Delta t} = \text{Change in airspeed per unit time (kt/sec)}$$

A power correction to insure ball-centered test data complied with the inherent sideslip family of curves depicting the UH-60A in the ESSS and four tanks configuration (fig.12, appendix E) was determined from ΔF_e as a function of sideslip angle (fig. 11) and equation 5 rewritten as follows.

$$SHP_{s/s} = \frac{(\Delta F_{e\ in\ s/s} - \Delta F_{e\ B-C})\ (\rho/\rho_o)\ (V_T^{\ 3})}{96254} \tag{8}$$

Where:

$\Delta F_e{}^*{}_{in\ s/s}$ = Change in equivalent flat plate area based on UH-60A inherent sideslip.

$\Delta F_e{}^*{}_{B-C}$ = Change in equivalent flat plate area based on the sideslip angle measured in ball-centered flight.

*Based on change in engine shaft horsepower.

Power required for level flight at the test day conditions was determined using the following equation.

$$SHP_t = SHP + SHP_{R/C} + SHP_{ACCEL} + SHP_{s/s} - SHP_{instr\ drag}{}^{-1.82} \tag{9}$$

9. Test day level flight data was corrected to average test day conditions by the following equations.

$$SHP_s = SHP_t \frac{(\delta_s\sqrt{\theta_s}) \left[\frac{N_R}{\sqrt{\theta}}\right]^3_s}{(\delta_t\sqrt{\theta_t}) \left[\frac{N_R}{\sqrt{\theta}}\right]^3_t} \tag{10}$$

$$V_{T_s} = V_{T_t} \frac{\left(\frac{N_R}{\sqrt{\theta}}\right)_s}{\left(\frac{N_R}{\sqrt{\theta}}\right)_t} \tag{11}$$

Where:

N_R = Main rotor speed (rev/min)

subscript t = Test day

subscript s = Average test day

Test data corrected for rate of climb, acceleration, instrumentation installation, and corrected to inherent sideslip, standard altitude, and ambient temperature are presented in figures 3 through 10, appendix E.

10. Level flight performance was determined by using equations 1 through 3, rewritten in the following form.

$$C_P = \frac{SHP(478935.3)}{\delta\sqrt{\theta}\left[\dfrac{N_R}{\sqrt{\theta}}\right]^3 \rho_o A R^3} \qquad (12)$$

$$C_T = \frac{GW(91.19)}{\delta\left[\dfrac{N_R}{\sqrt{\theta}}\right]^2 \rho_o A R^2} \qquad (13)$$

$$\mu = \frac{V_T(16.12)}{R\sqrt{\theta}\left(\dfrac{N_R}{\sqrt{\theta}}\right)} \qquad (14)$$

Where:

478935.3 = Conversion factor (ft-lb-sec^2-rev^3/min^3-SHP)

91.19 = Conversion factor (sec^2-rev^2/min^2)

16.12 = Conversion factor (ft-rev/min-kt)

11. Data analysis was accomplished by plotting C_P versus μ for each test at the average C_T. The curves through these data were then cross-faired as C_P versus C_T for lines of constant μ (figs. 1 and 2, app E). This carpet plot allows determination of power required as a function of airspeed and C_T.

12. The specific range (SR) data were derived from the test level flight power required and fuel flow (W_{F_t}). Selected level flight performance SHP and fuel flow data for each engine were referred as follows.

$$SHP_{REF} = \frac{SHP_t}{\delta\theta^{0.5}} \tag{15}$$

$$W_{F_{REF}} = \frac{W_{F_t}}{\delta\theta^{0.55}} \tag{16}$$

A curve fit was subsequently applied to the referred data and used as the basis to correct W_{F_t} to standard day fuel flow using the following equation.

$$W_{F_s} = W_{F_t} + \Delta W_F \tag{17}$$

Where:

ΔW_F = Change in fuel flow between SHP_t and SHP_s

The following equation was used for determination of specific range.

$$SR = \frac{V_{T_s}}{W_{F_s}} \tag{18}$$

Stabilator Position Effect:

13. The change in power required to correct for dimensional differences attributed to stabilator position was obtained from USAAEFA Final Report No. 83-24, figure 69, appendix E (ref 7,

app A). The fairings from this figure were cross-faired as ΔC_p versus stabilator position for specific μ's and applied to the fairings through the dimensional flight conditions obtained at forward longitudinal cg (figs. 9 and 10, app E). The test data at 11,780 feet density altitude (fig. 8) was used as the base line ($\Delta C_p = 0$) since only the longitudinal cg was different for this test data from the base line data used throughout this evaluation. The following equation was used to determine the power required to account for stabilator position.

$$C_p = C_{P(\text{base line})} \pm \Delta C_{P\ \text{stabilator}}$$

Where:

+ or - is employed depending on direction of stabilator movement when transversing from base line to test condition 2.
+ ;Stabilator trailing edge up
- ;Stabilator trailing edge down

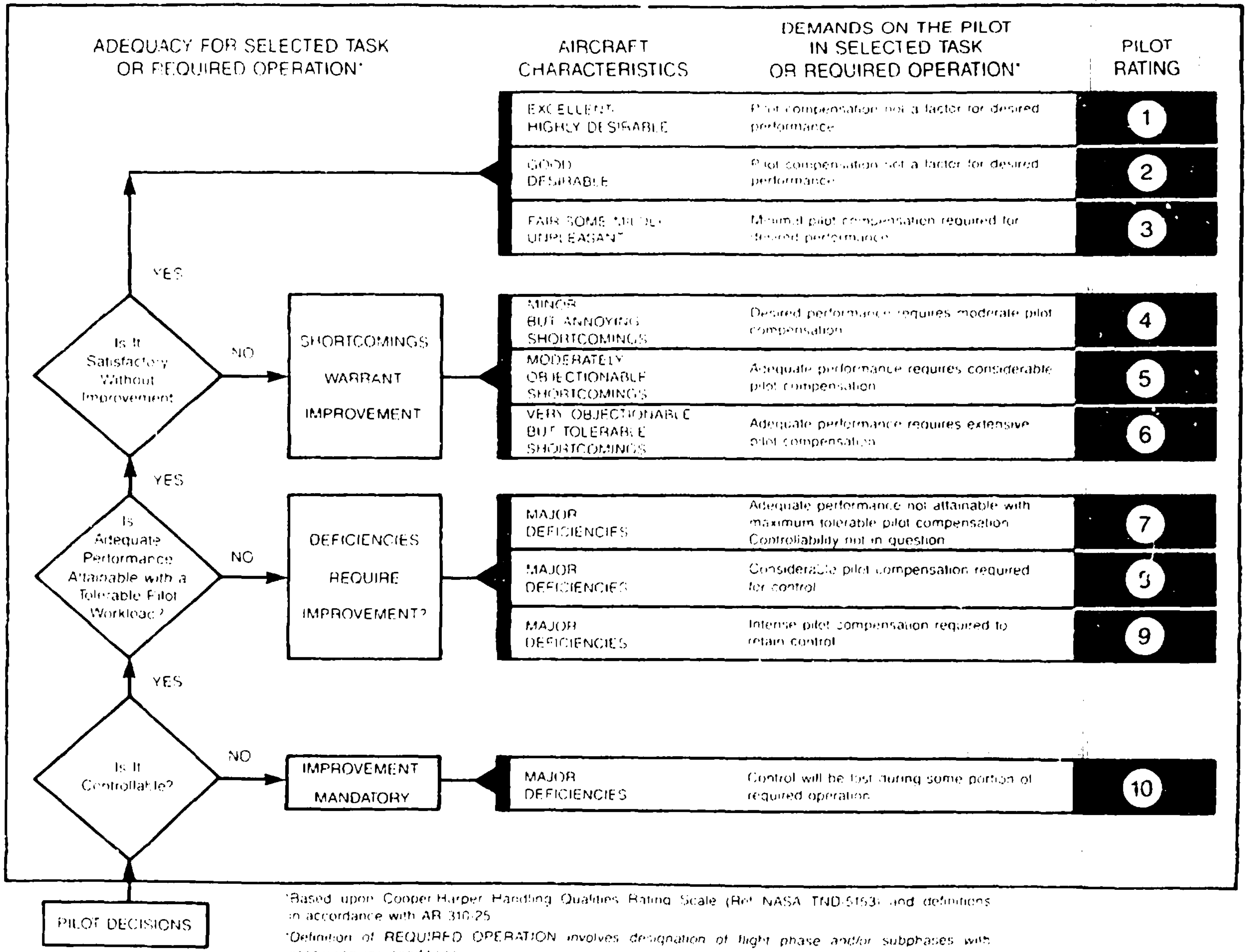
DEFINITION

Shortcoming

14. An imperfection or malfunction occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the materiel or end product.

QUALITATIVE RATING SCALE

15. A Handling Qualities Rating Scale (HQRS) was used to augment pilot comments and is presented in figure 1.



*Based upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) and definitions in accordance with AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions

Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

Figure	Figure Number
Nondimensional Level Flight Performance	1 and 2
Dimensional Level Flight Performance	3 through 10
Change in Equivalent Flat Plate Area with Sideslip	11
Inherent Sideslip	12
Control Positions in Trimmed Level Flight	13 through 15
Ship System Airspeed Calibration	16 through 18

FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

CONFIGURATION: ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG: FS 350.0
3. MID LATERAL CG
4. REFERRED ROTOR SPEED: 258 RPM
5. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 6

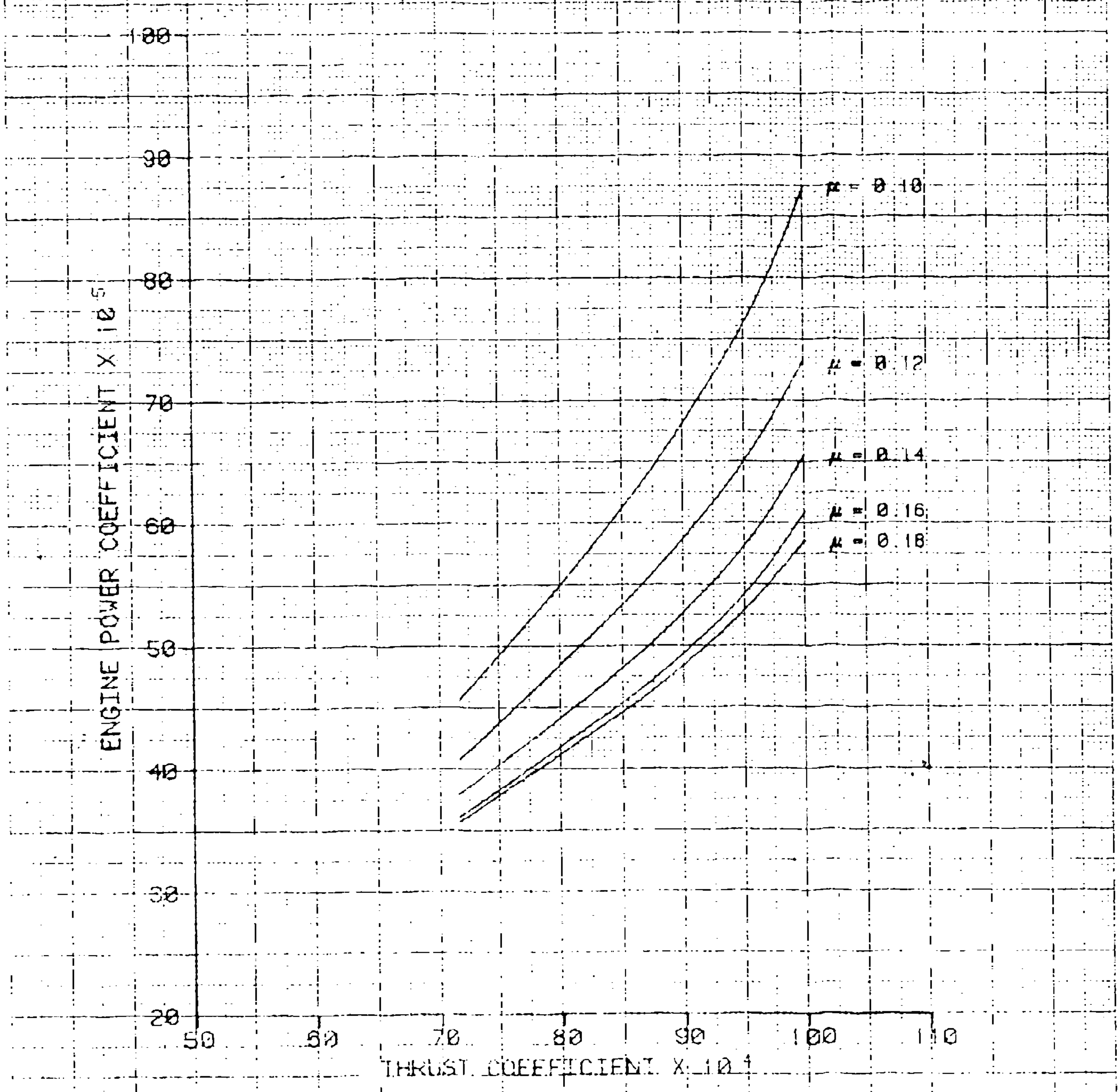
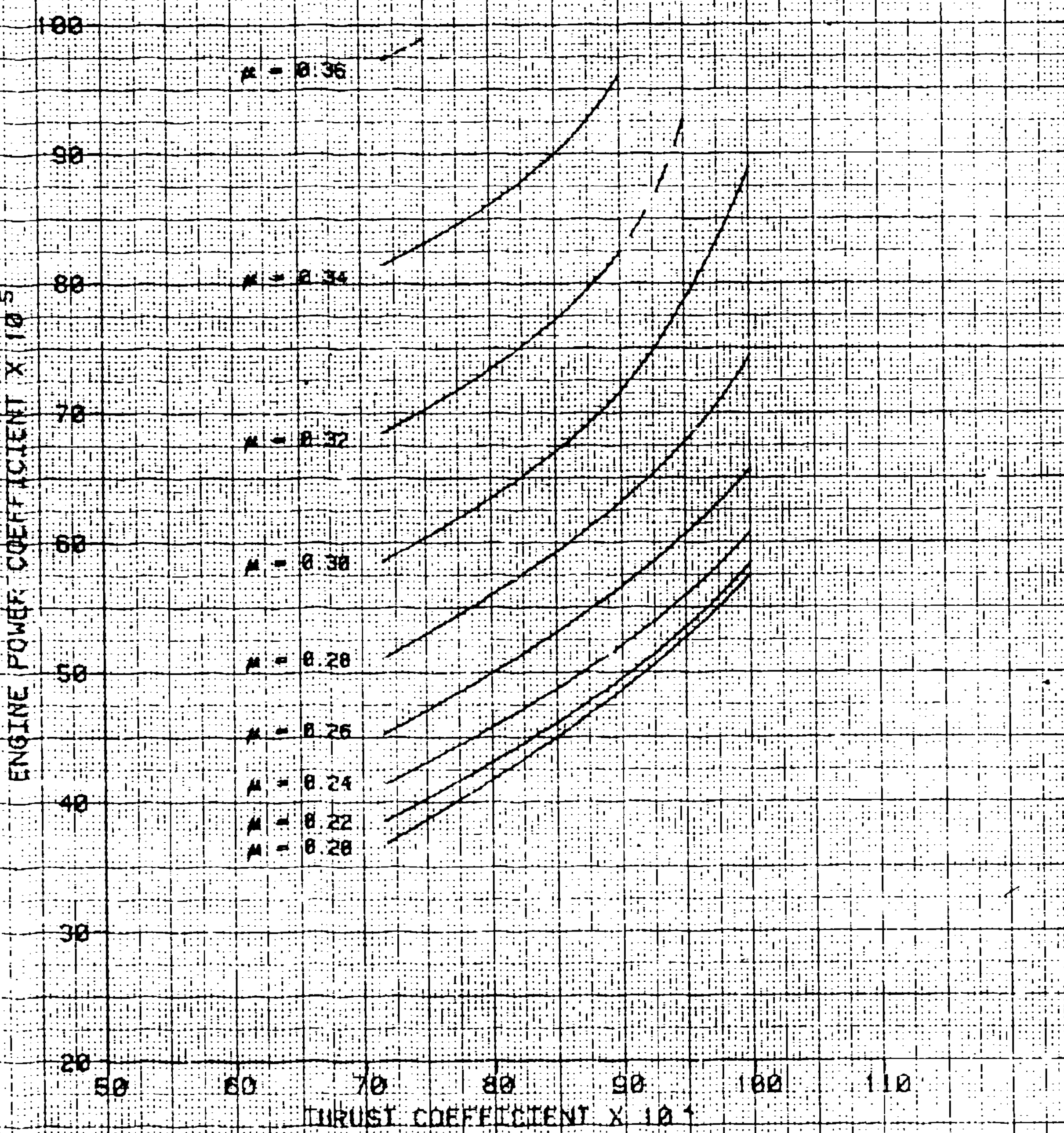


FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

CONFIGURATION: ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG: FS 350.0
3. MID LATERAL CG
4. REFERRED ROTOR SPEED: 258 RPM
5. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 6



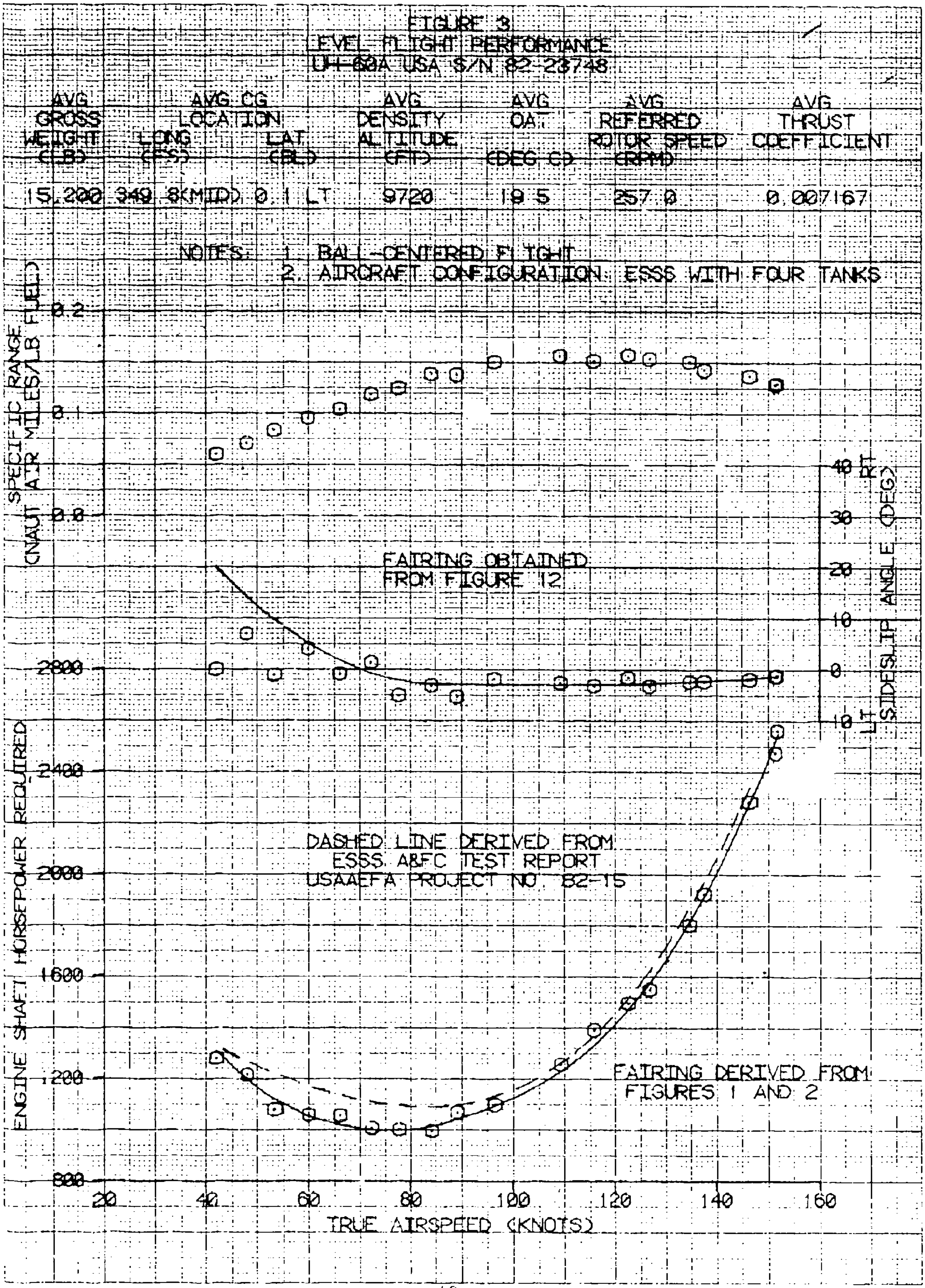


FIGURE 3
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

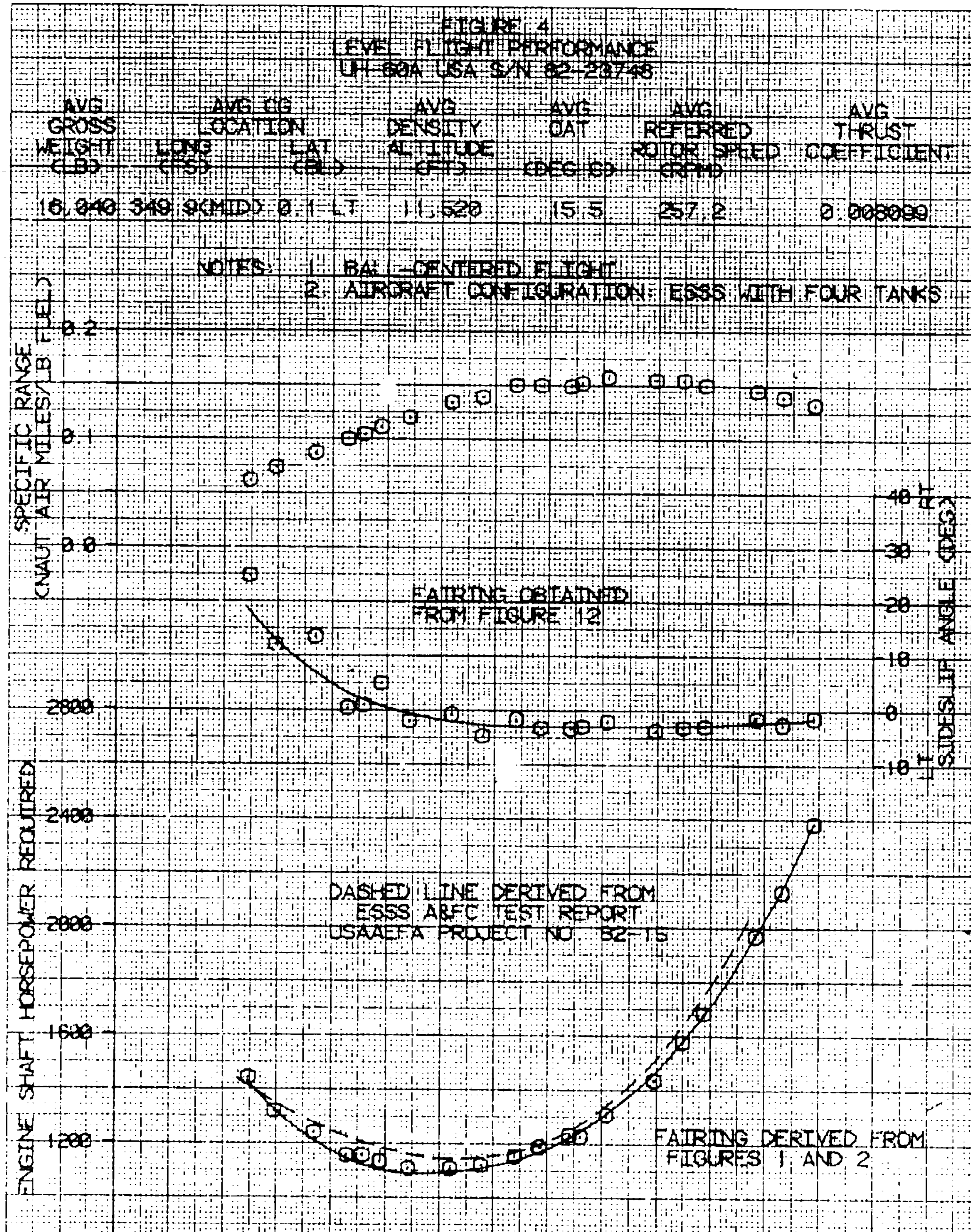


FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

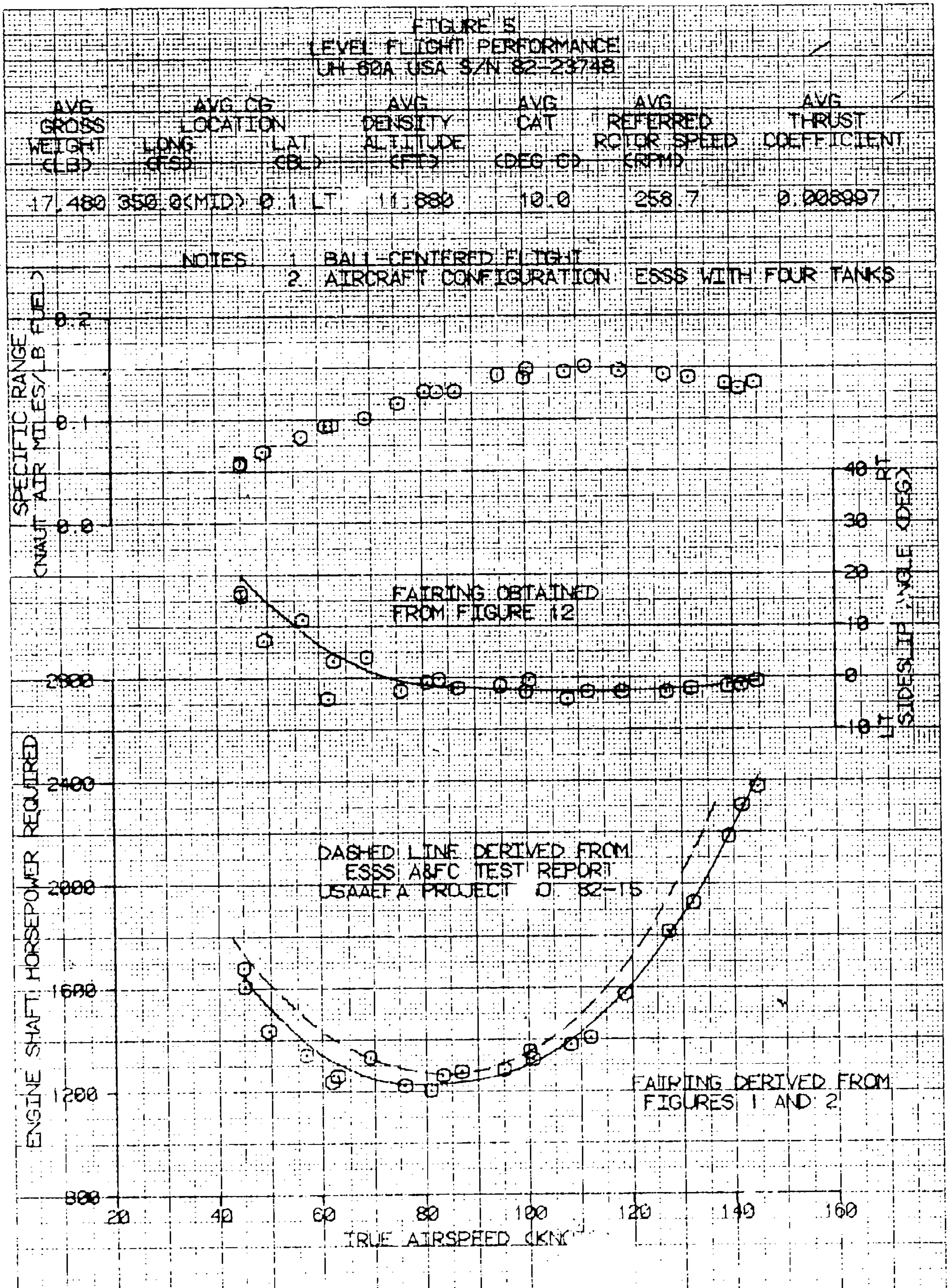


FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG (FS) LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG REFERRED ROTOR SPEED (RPM)
AVG THRUST COEFFICIENT
17,480 350.0(MID) 0.1 LT 11,880 10.0 258.7 0.008997
NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS
SPECIFIC RANGE (NAUT AIR MILES/LB FUEL)
SIDESLIP ANGLE (DEG)
RT
LT
FAIRING OBTAINED FROM FIGURE 12
DASHED LINE DERIVED FROM ESSS A&FC TEST REPORT USAAEFA PROJECT NO. 82-15
FAIRING DERIVED FROM FIGURES 1 AND 2
ENGINE SHAFT HORSEPOWER REQUIRED
TRUE AIRSPEED (KN

FIGURE 6
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
19,260	350.1(MID)	0.1 LT	11,880	7.5	258.7	0.01001

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS

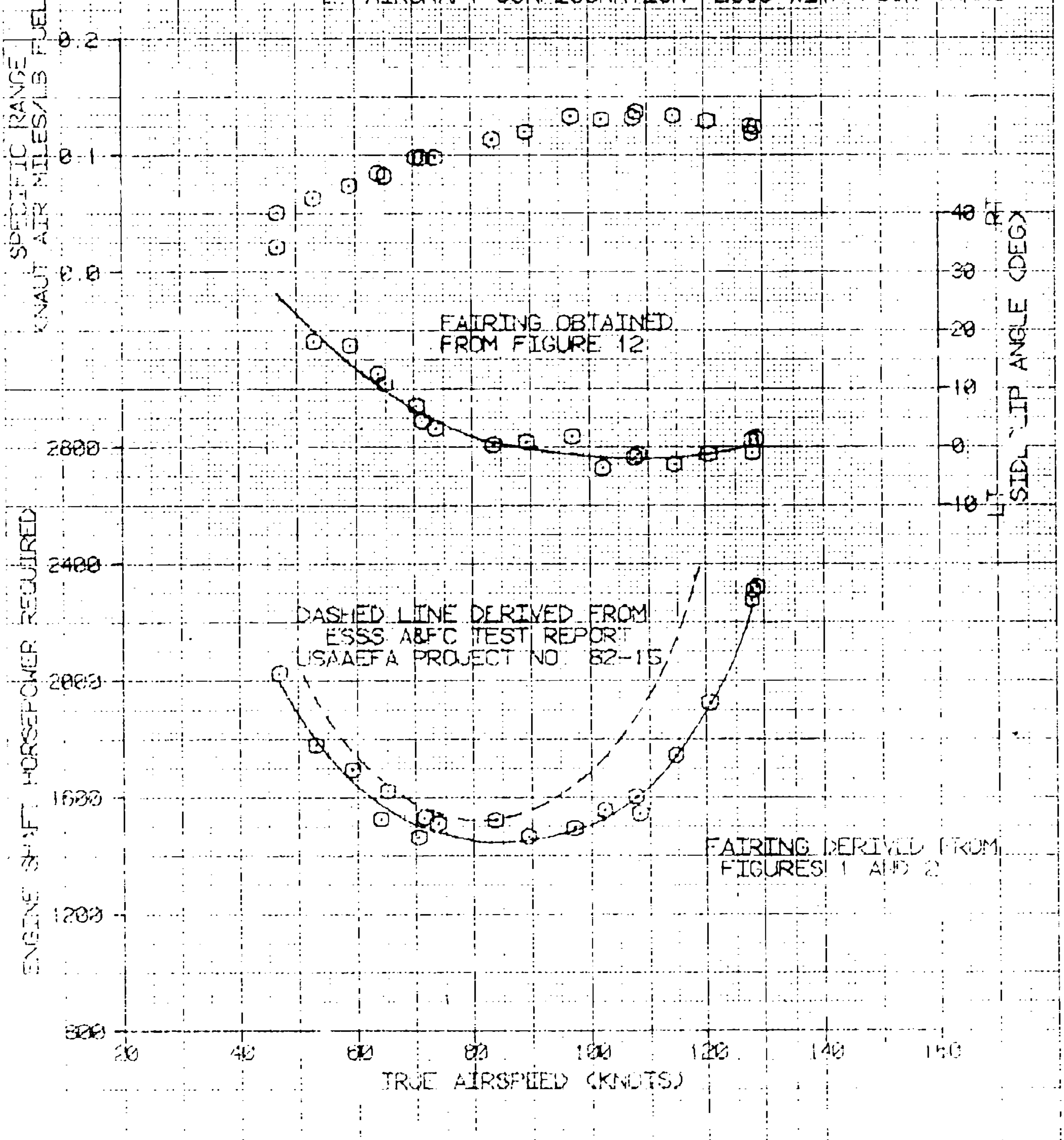


FIGURE 7
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
17,440	357.7(AFT)	0.1 LT	12,100	-12.0	256.2	0.009152

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS

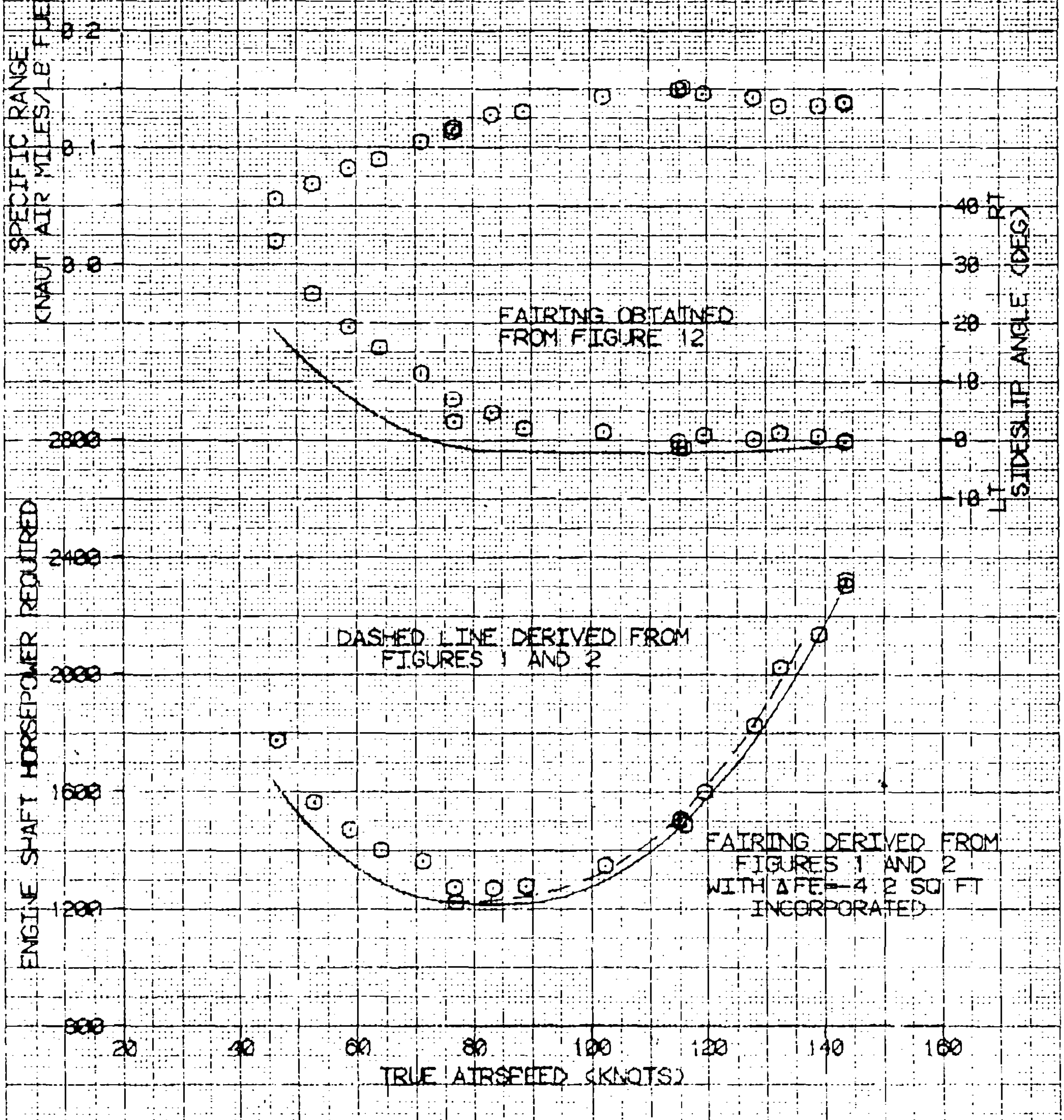
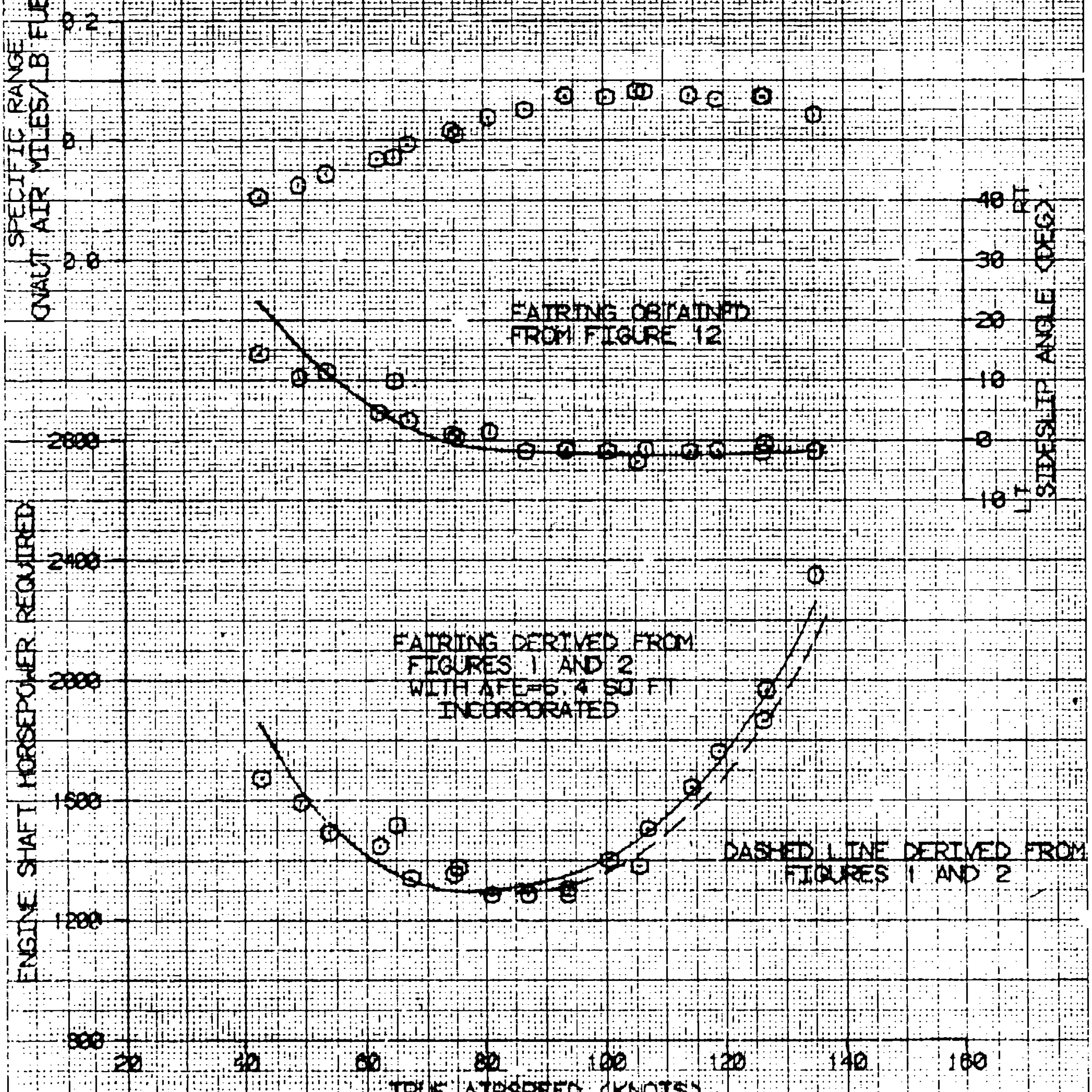


FIGURE 8
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
18,060	341.8(FWD)	0.1 LT	11,780	15.0	257.1	0.009218

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS



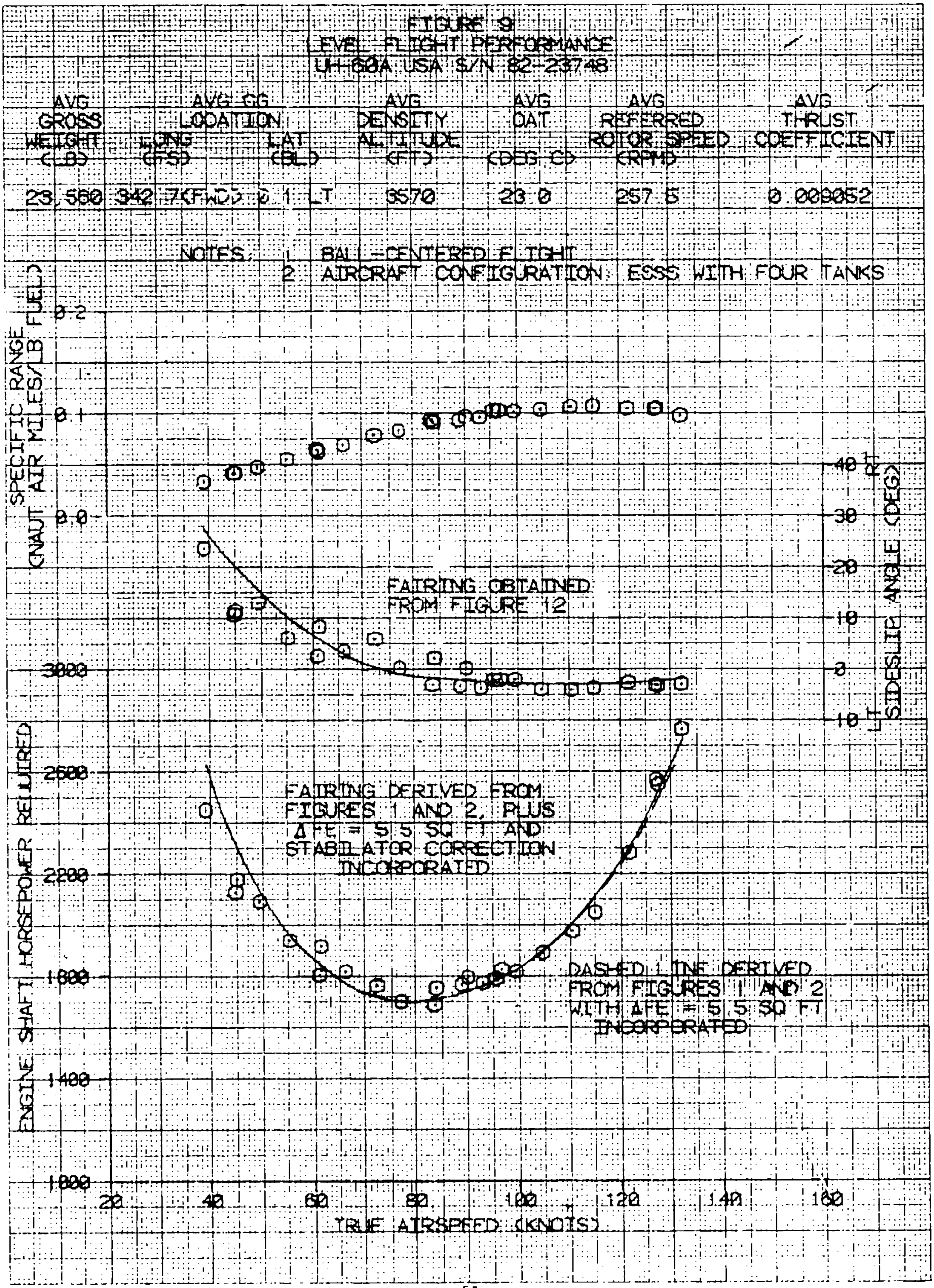


FIGURE 9
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG (FS) LAT (BL)
AVG DENSITY ALTITUDE (FT)
AVG OAT (DEG C)
AVG REFERRED ROTOR SPEED (RPM)
AVG THRUST COEFFICIENT
23,560 342.7(FWD) 0.1 LT 5570 23.0 257.5 0.009052
NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS
SPECIFIC RANGE (NAUT AIR MILES/LB FUEL)
0.2
0.1
0.0
SIDESLIP ANGLE (DEG)
RT
40
30
20
10
0
-10
LT
FAIRING OBTAINED FROM FIGURE 12
ENGINE SHAFT HORSEPOWER REQUIRED
3000
2600
2200
1800
1400
1000
FAIRING DERIVED FROM FIGURES 1 AND 2, PLUS ΔFE = 5.5 SQ FT AND STABILATOR CORRECTION INCORPORATED
DASHED LINE DERIVED FROM FIGURES 1 AND 2 WITH ΔFE = 5.5 SQ FT INCORPORATED
20 40 60 80 100 120 140 160
TRUE AIRSPEED (KNOTS)

FIGURE 10
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
21,140	342.6(FWD)	0.1 LT	6590	18.0	257.8	0.009034

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS

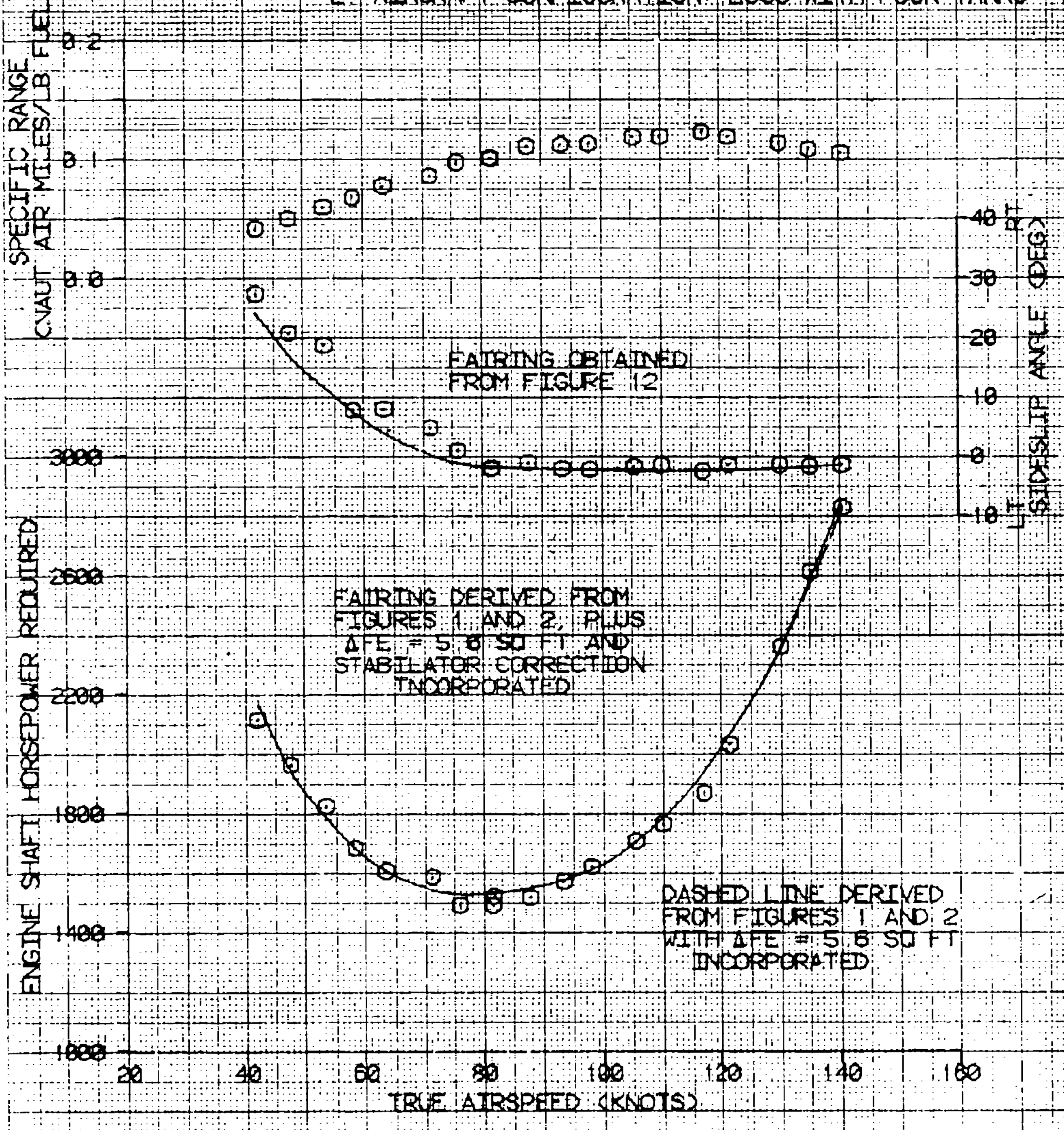


FIGURE 11
CHANGE IN EQUIVALENT FLAT PLATE AREA WITH SIDESLIP
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG TRUE AIRSPEED (KNOTS)	AVG THRUST COEFFICIENT
⊙	17,080	350.2(MID)	0.1 LT	12,560	9.5	122	0.009035
□	18,920	350.2(MID)	0.1 LT	13,310	7.0	110	0.010017

NOTES: 1. TRIMMED LEVEL FLIGHT CONDITION
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS
3. AVERAGE REFFERRED ROTOR SPEED: 258.5 RPM

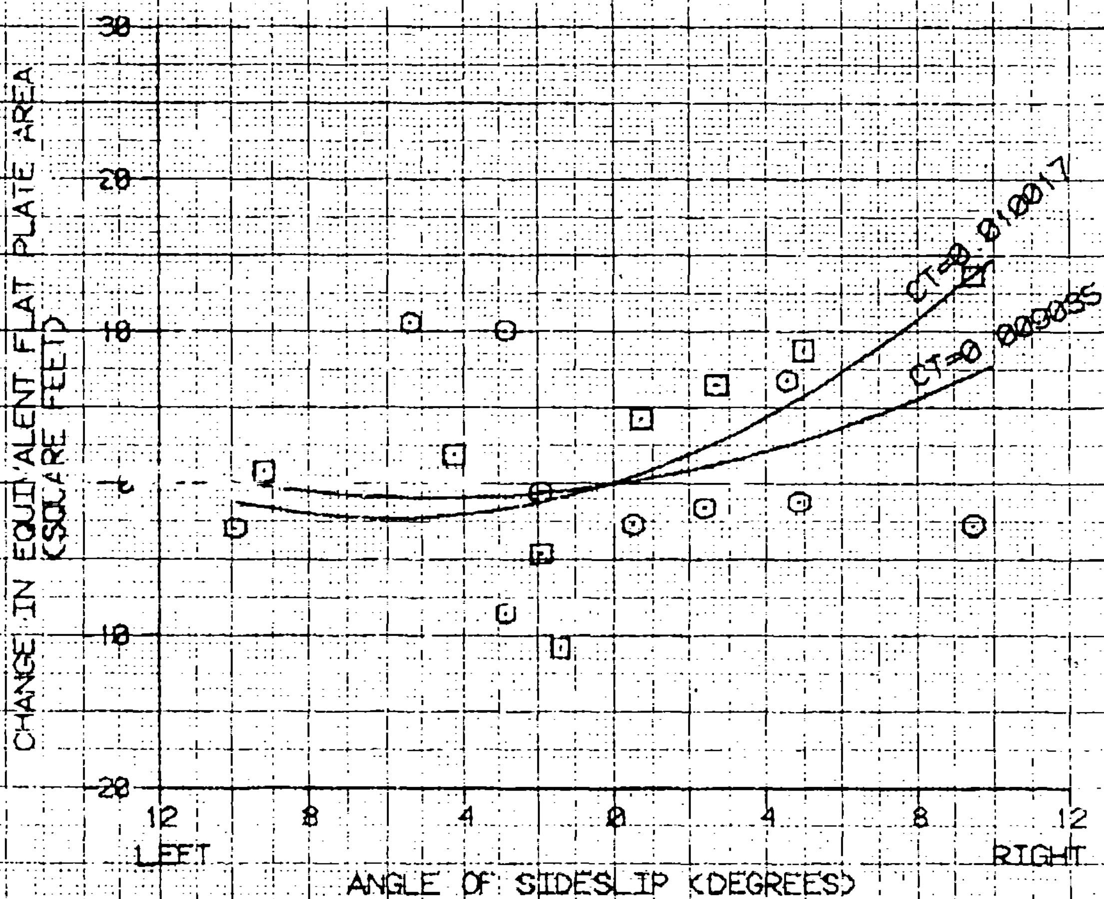


FIGURE 12
INHERENT SIDESLIP ANGLE
UH-60A USA S/N 82-23748

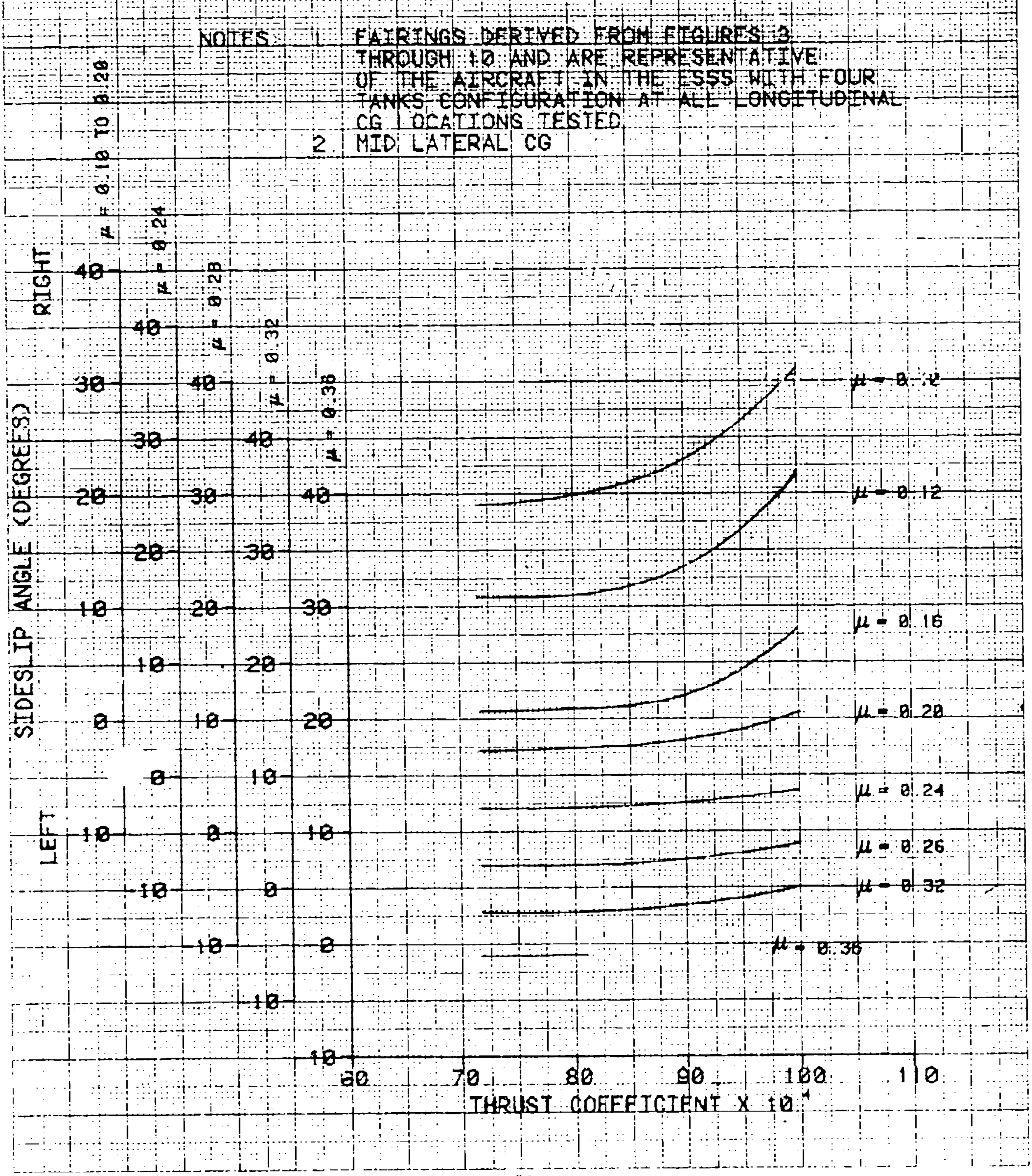


FIGURE 18
CONTROL POSITIONS AND AIRCRAFT ATTITUDES IN TRIMMED LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
⊙	15,200	349.8(MID)	0.1 LT	9720	19.5	257.0	0.007167
□	16,840	349.9(MID)	0.1 LT	11,520	15.5	257.2	0.008099
△	17,480	350.0(MID)	0.1 LT	11,880	10.0	258.7	0.008997
◇	19,250	350.1(MID)	0.1 LT	11,880	7.5	258.7	0.010001

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS

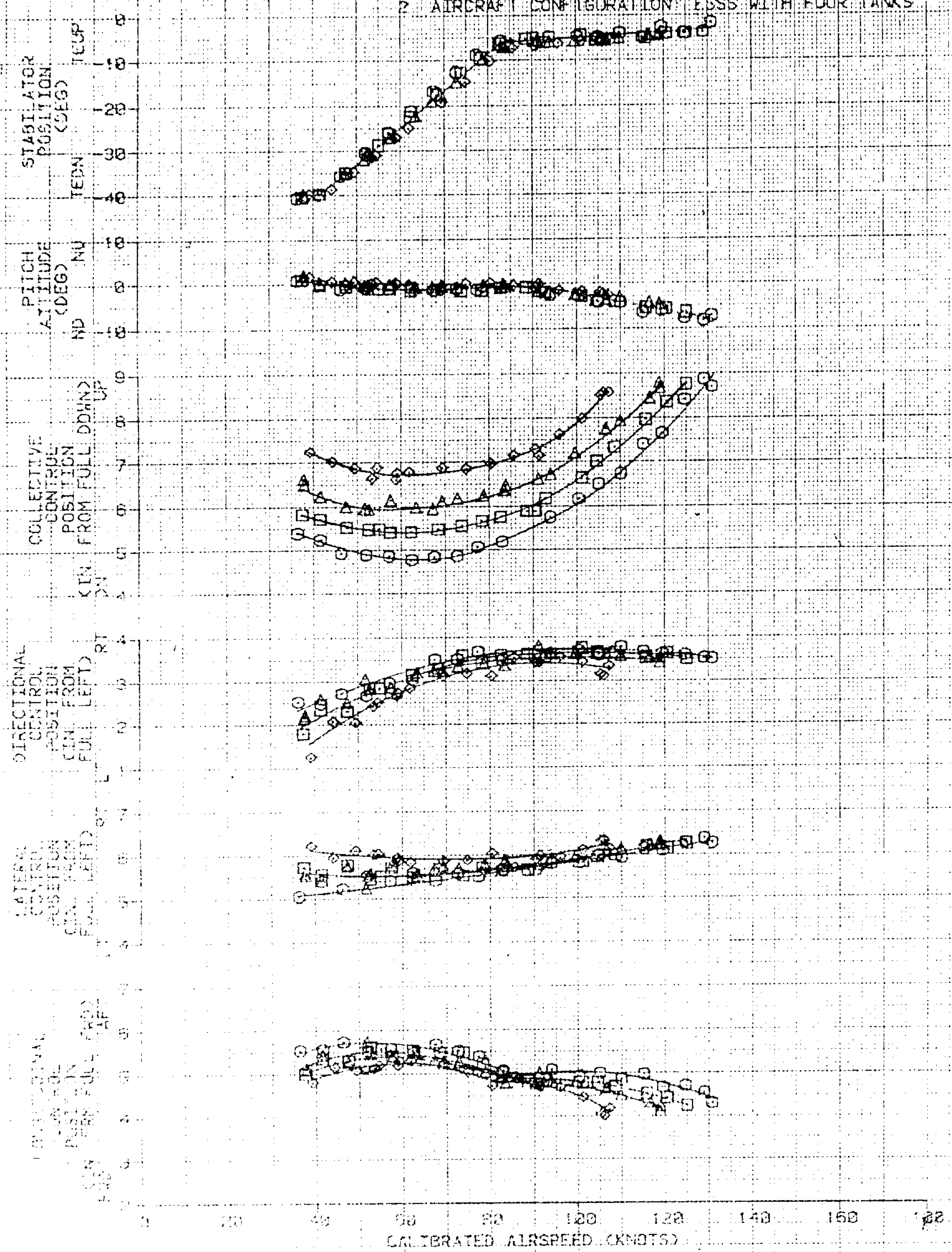


FIGURE 15
CONTROL POSITIONS AND AIRCRAFT ATTITUDES IN TRIMMED LEVEL FLIGHT
UH-60A USA S/N 82-23746

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
○	18,060	341.8(FWD)	0.1 LT	11,780	15.0	257.1	0.009218
□	21,140	342.0(FWD)	0.1 LT	6590	18.0	257.8	0.009084
△	23,560	342.7(FWD)	0.1 LT	3570	23.0	257.5	0.009052

NOTES: 1. BALL-CENTERED FLIGHT
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS

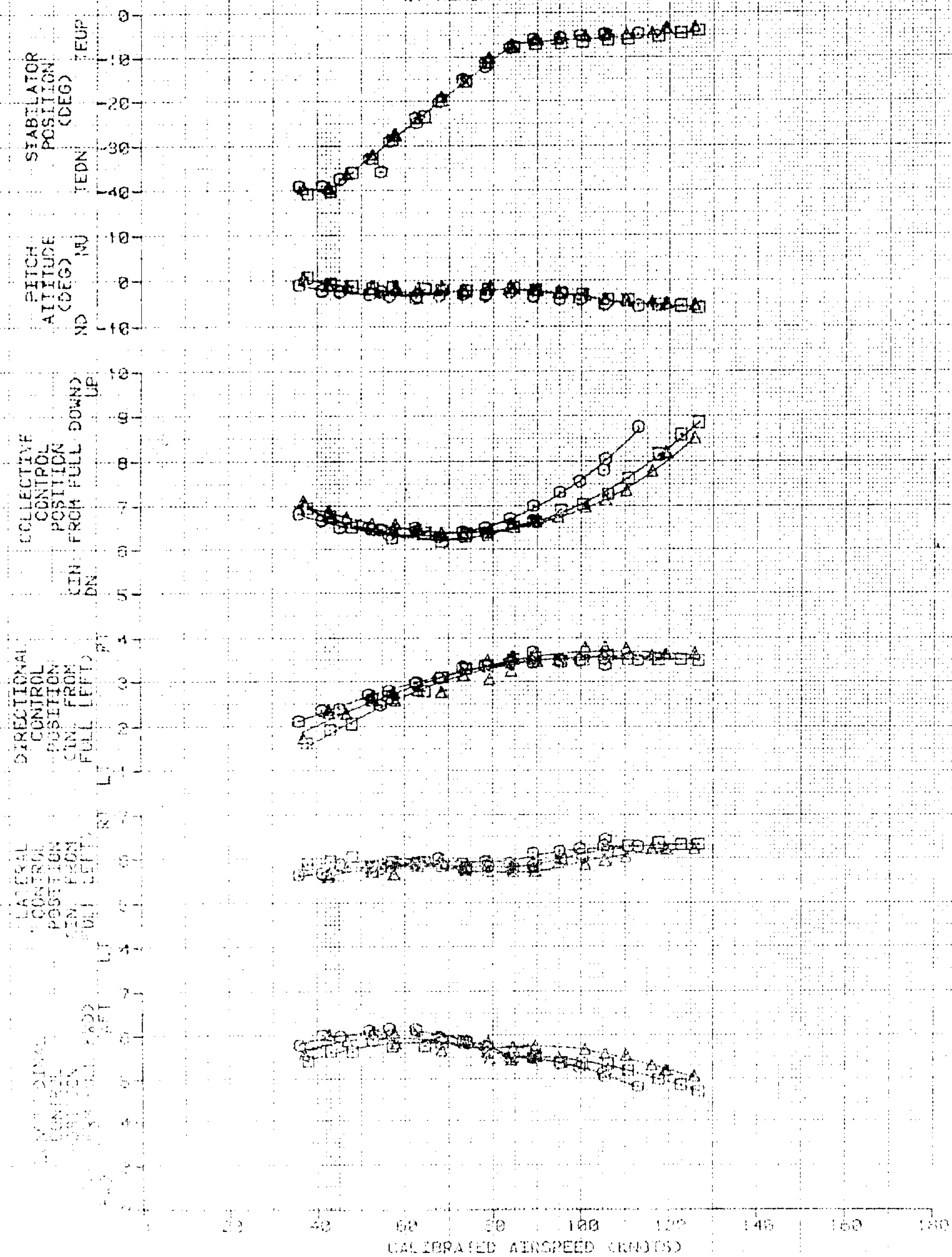


FIGURE 16
SHIP SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AIRCRAFT CONFIGURATION
○	16,920	349.8 MID	0.1 LT	6180	19.0	258	ESSS WITH FOUR TANKS
⊗	16,400	351.0 AFT	0.2 RT	5100	7.0	257	NORMAL UTILITY
□	20,880	349.9 MID	0.1 LT	6580	20.0	258	ESSS WITH FOUR TANKS
⊠	21,900	358.5 AFT	0.2 RT	5600	9.5	258	NORMAL UTILITY

NOTES: 1. PACE CALIBRATION METHOD
2. BALL-CENTERED FLIGHT
3. CROSSED SYMBOLS DENOTE DATA OBTAINED FROM USAAEFA FINAL REPORT NO. 84-28

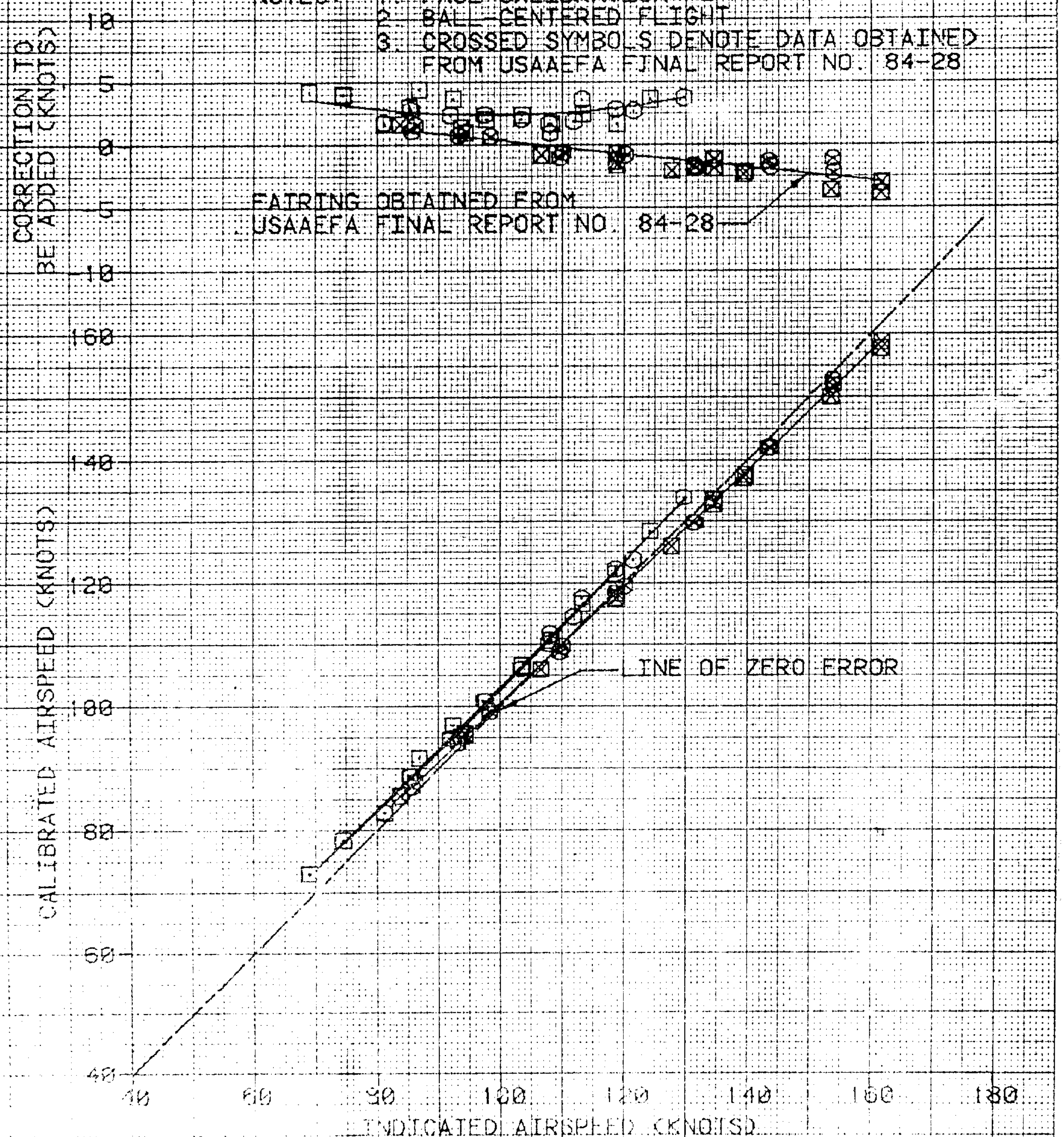


FIGURE 16
SHIP SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AIRCRAFT CONFIGURATION
○	16,020	349.6 MID	0.1 LT	6180	19.0	258	ESSS WITH FOUR TANKS
⊗	16,400	361.0 AFT	0.2 RT	5100	7.0	257	NORMAL UTILITY
□	20,880	349.9 MID	0.1 LT	6580	20.0	258	ESSS WITH FOUR TANKS
⊠	21,900	358.5 AFT	0.2 RT	5600	9.5	258	NORMAL UTILITY

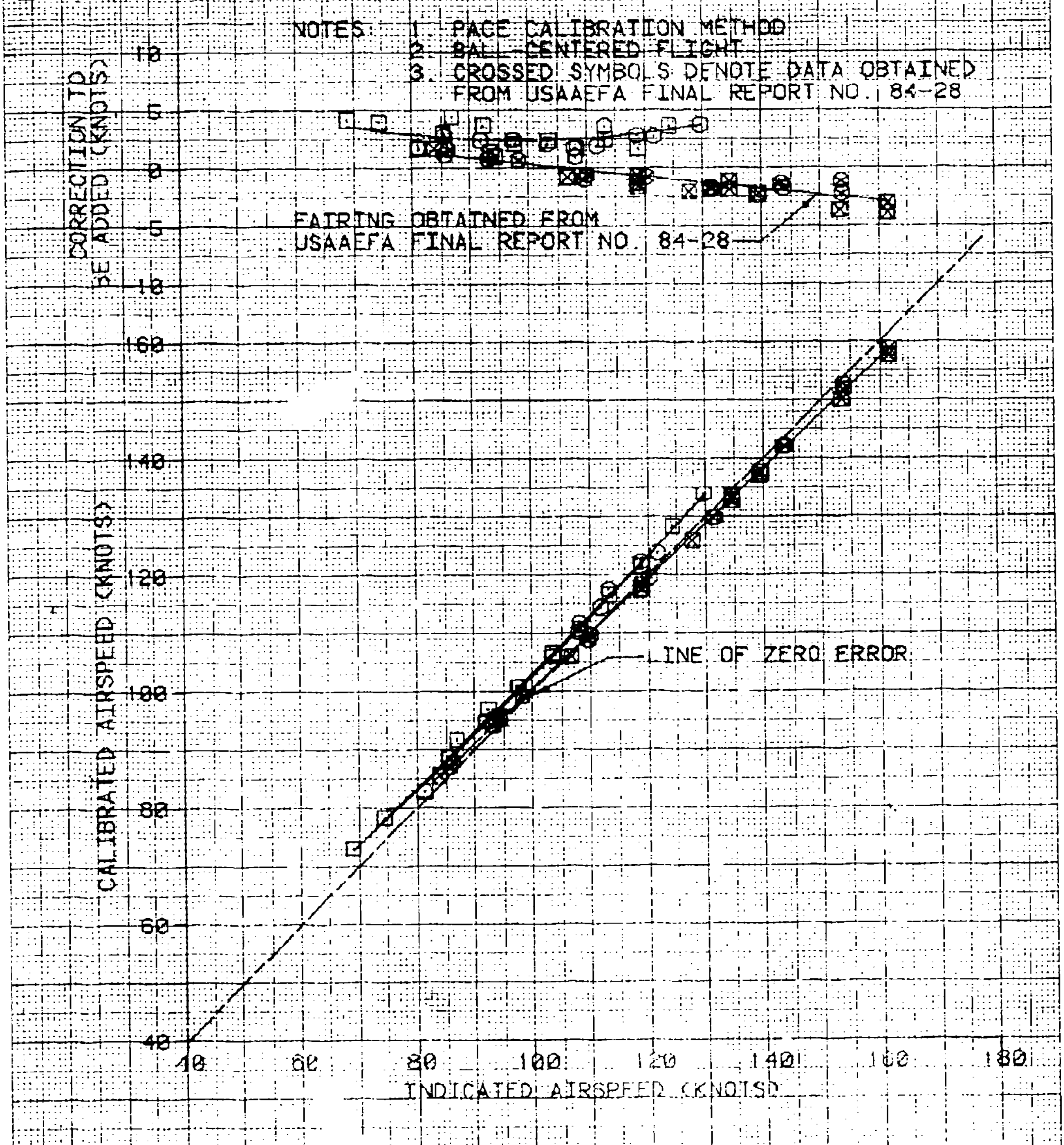


FIGURE 17
SHIP SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG. DENSITY ALTITUDE (FT)	AVG. OAT (DEG C)	AVG. ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
⊙	15,200	349.8(MID)	0.1 LT	9720	19.5	259	0.007167
⊡	16,040	349.9(MID)	0.1 LT	11,520	15.5	257	0.008099
△	17,480	350.0(MID)	0.1 LT	11,880	10.0	256	0.008997
◇	19,260	350.1(MID)	0.1 LT	11,880	7.5	255	0.010001

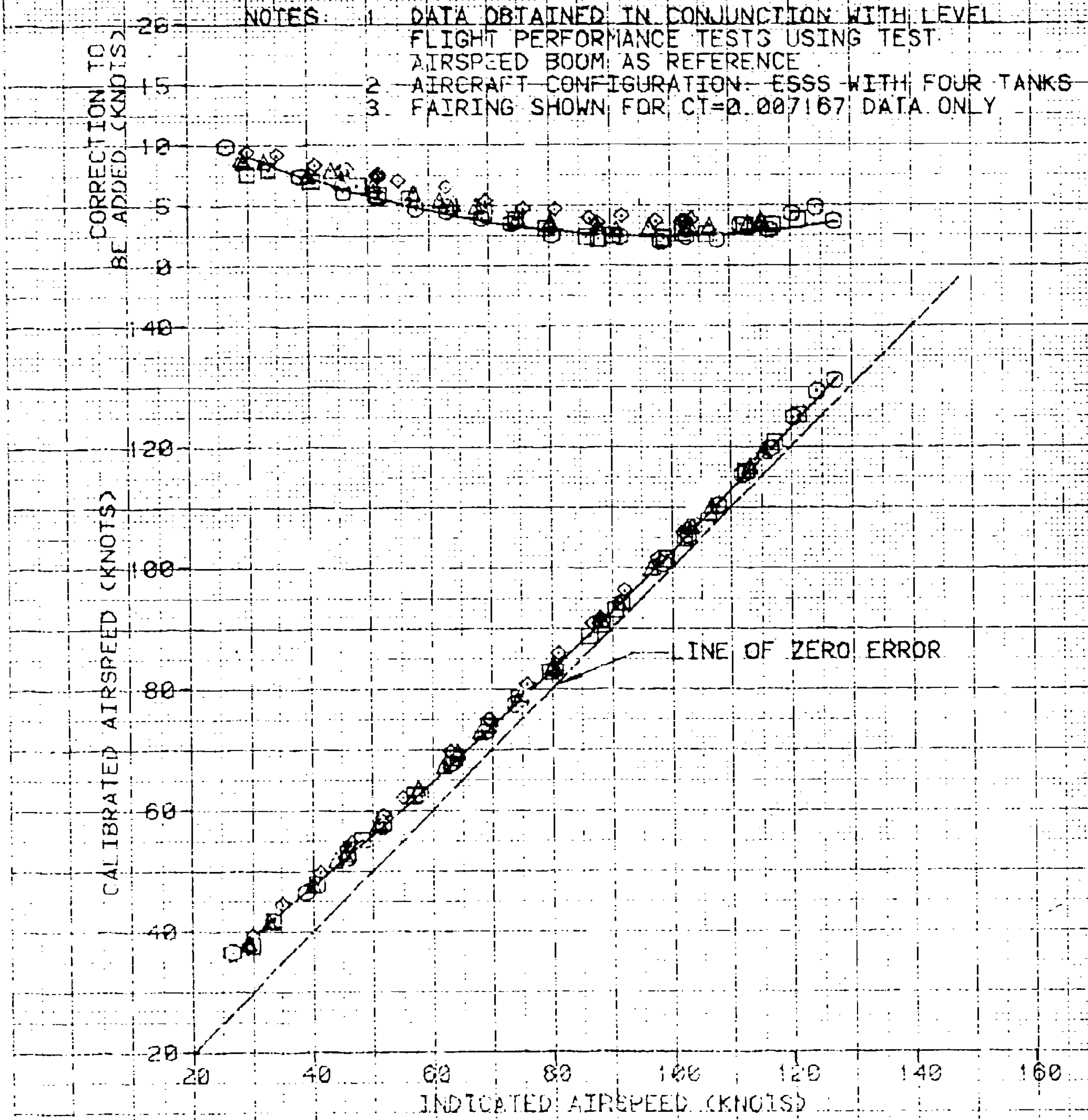
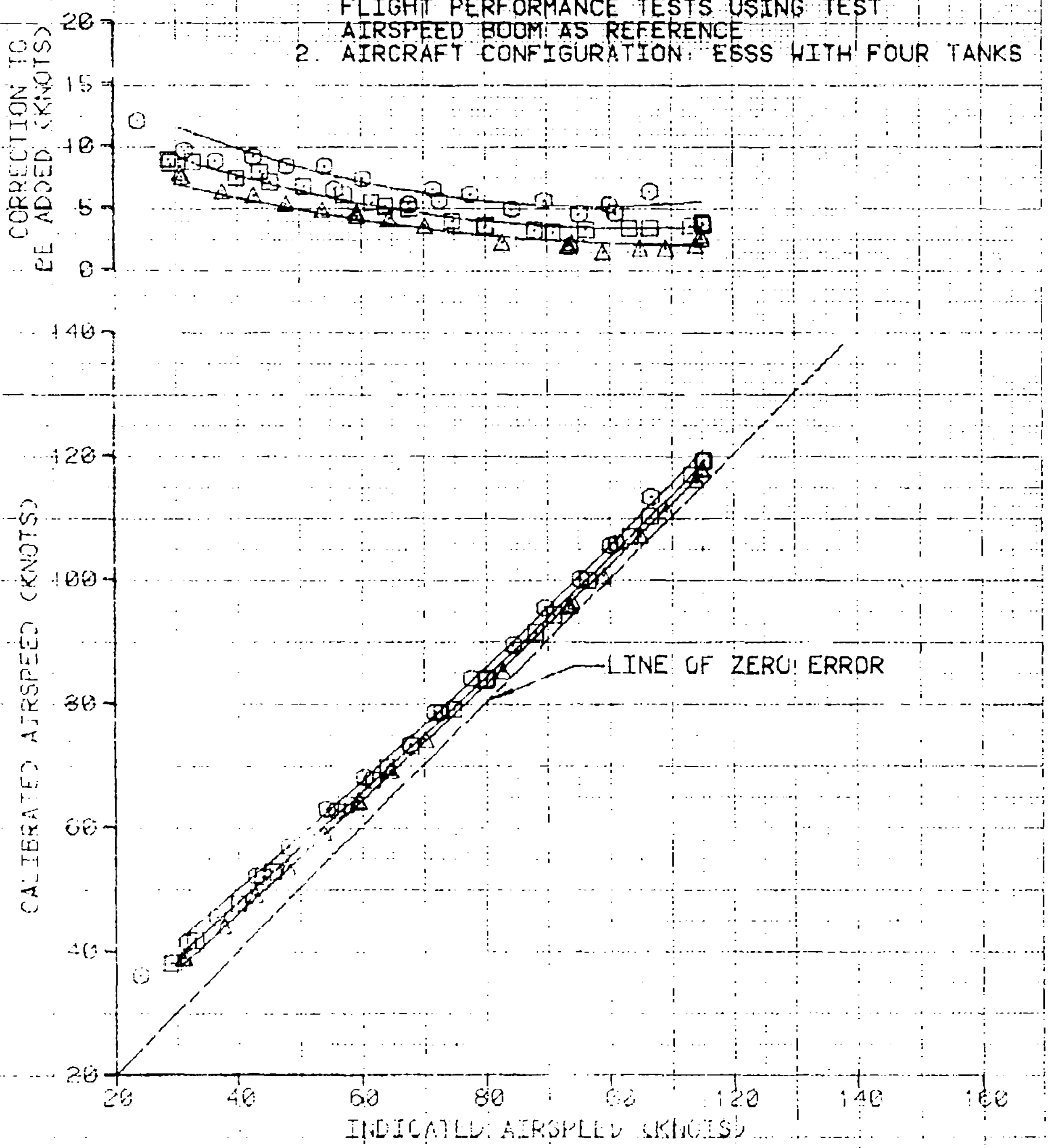


FIGURE 18
SHIP SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 82-23748

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
○	18,060	341.8(FWD)	0.1 LT	11,780	15.0	257	0.009218
□	17,480	350.0(MID)	0.1 LT	11,880	10.0	256	0.008997
△	17,440	357.7(AFT)	0.1 LT	12,100	12.0	255	0.009152

NOTES: 1. DATA OBTAINED IN CONJUNCTION WITH LEVEL FLIGHT PERFORMANCE TESTS USING TEST AIRSPEED BOOM AS REFERENCE
2. AIRCRAFT CONFIGURATION: ESSS WITH FOUR TANKS



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